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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CIX.—No. 2829.] *LONDON: FRIDAY, MARCH 19, 1920.* [*Registered at the General Post Office as a Newspaper.*] [PRICE... 1s. BY FOREIGN POST...1s. 4½d.

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See page 17, March 12 8205

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See page 15, March 12. 8431

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8194
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See Advertisement page 90.

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BIRMINGHAM WAREHOUSES—MILK STREET, SHEEPCOTE STREET.
See Advertisement page 26. 8197

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Great saving of labour. No noise. No dust. No dirt. Ashes discharged 30ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4536

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Engines and Dynamos could be sold separately.
Also TWO 500 Kw. Parsons TURBINES, 230-250 Volts, D.C. (in series 460-500 volts), complete with Spare Armature and Condenser.
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7799
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See Advertisement page 86, March 12. 2402

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See Full Page Advt., page 93, March 5.

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See Full Page Advertisement, March 5.

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See Advt. Page 36, Mar. 12.
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For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
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Tuition. Also Postal Courses in Mechanical Engineering, Aircraft Design and Mathematics.—PENNINGTONS, 384, Oxford Road, Manchester.

TENDERS.

MANCHESTER SHIP CANAL.

CONTRACT No. 184.

The Directors of the Manchester Ship Canal Company are prepared to receive

Tenders for the Construction

and DELIVERY of a REINFORCED CONCRETE CAISSON required at the Oil Dock, now in course of construction at Stanlow, on the northerly side of the Manchester Ship Canal, in the Urban District of Ellesmere Port and Whitby, in the County of Chester.

The Drawings may be inspected and copies of the Specifications, Bill of Quantities and Form of Tender obtained at the Office of the Chief Engineer Mr. H. A. REED, M.Inst.C.E., 41, Spring Gardens Manchester, on and after 15th March, 1920, on payment of a deposit of two guineas, which will be returned on receipt of a bona fide Tender.

Sealed Tenders addressed to the undersigned, and endorsed "Tender for Reinforced Concrete Caisson," should be delivered at this Office on or before 10 a.m., on Thursday, April 8th, 1920.

F. A. BYRE,
Secretary.
41, Spring Gardens, Manchester. F 313

CLYDE NAVIGATION.

PLANT FOR SALE AT PRINCE'S DOCK POWER STATION.

The Trustees invite

Tenders for the Purchase of

DISUSED PLANT at Prince's Dock Power Station, consisting of a BELLISS DOUBLE-ACTING COMPOUND STEAM ENGINE, on Combined Soleplate coupled to a Silvertown Compound Dynamo of 80 Kw. and 250 volts D.C.; a MIRRLEES WATSON SINGLE-ACTING COMPOUND STEAM ENGINE with Dynamo of similar type and size; also STEAM and EXHAUST PIPES, etc.; and Seven MARBLE PANEL SWITCHBOARDS, with FITTINGS.

The Purchaser to take down and remove the Plant when required by the Trustees.

For particulars apply to the Mechanical Engineer, 16, Robertson Street.

Tenders to be lodged with the undersigned not later than Monday, 12th April.

The Trustees may not accept the highest or any Tender.

T. R. MACKENZIE,
General Manager and Secretary.
16, Robertson Street, Glasgow,
12th March, 1920. F 296

North Eastern Railway.—

WAGON WORKS, FAVERDALE, DARLINGTON.—TO BUILDERS AND CONTRACTORS. The Directors are prepared to receive TENDERS for the ERECTION of WAGON BUILDING WORKS at Faverdale, Darlington, comprising: Forge, Shops, Offices, etc., totalling approximately a floor area of 70,000 super yards, 800 tons of Cast Iron and 3,120 tons of Steel and Iron.

ARCHITECTURAL WORKS:—EXCAVATOR, BRICKLAYER and MASON, CARPENTER and JOINER, SLATER, PLASTERER, PLUMBER and GLAZIER, IRONFOUNDER and PAINTER. ENGINEERING WORKS:—EXCAVATION OVER SITE, DRAINAGE and SEWERAGE, ROAD MAKING, FENCING and GATES, and BALLASTING.

Plans and Specification may be seen, and Quantities and further information obtained upon application to Mr. ARTHUR POLLARD, the Company's Architect at York on and after 15th March. Quantities supplied on personal application to parties tendering for the whole of the works. Sealed Tenders, marked "Wagon Works, Darlington," to be sent to the Secretary at York not later than Nine a.m. on 12th April. The Directors do not bind themselves to accept the lowest or any Tender.

W. H. D. DEVEY,
for the Secretary.
York, 6th March 1920. F 142

METROPOLITAN BOROUGH OF SHOREDITCH.

ELECTRICITY SUPPLY DEPARTMENT.

Tenders are Invited for the

SUPPLY, DELIVERY and ERECTION of the following PLANT:—

One WATER-TUBE BOILER, 33,000 lbs. evaporative capacity.
One 5000 Kw. TURBO-ALTERNATOR, A.C., 6600 volts
H.H.T. and D.C. SWITCHGEAR.

Specifications and Forms of Tender can be obtained upon application to the undersigned.

C. NEWTON RUSSELL,
Borough Electrical Engineer.
Electricity Supply Department,
Coronet Street, Shoreditch, N. 1. F 309

CLYDE LIGHTHOUSES TRUST.

The Trustees invite

Enquiries for the Sale or Hire

of their DREDGER "WILLIAM H. RAEBURN" which is in excellent order. The Dredger is at present in the West Harbour, Port-Glasgow. It is capable of dredging 500 tons per hour at 42 feet depth, self-propelling, speed 5 knots; two sets of buckets large and small.

Further particulars of the vessel from Messrs. D. & C. STEVENSON, Civil Engineers, 84, George Street, Edinburgh.

Enquiries for sale or hire to be made to the undersigned.

J. F. ANDERSON,
Clerk to the Trustees.
137, St. Vincent Street,
Glasgow.
11th March, 1920. F 277

CITY OF MANCHESTER.

The Electricity Department

have FOR SALE, SIX Babcock & Wilcox Land-type WATER-TUBE BOILERS, each with a maximum evaporation of 18,000 lbs. per hour. Working pressure 200 lb. per sq. in. In good condition and the Insurance Company's reports can be inspected. The Boilers can be seen Mondays to Fridays, 10 a.m. to 12 noon, and 2 p.m. to 4 p.m., at the Stuart Street Electricity Works, Bradford, Manchester. The purchaser will be required to bear the costs of dismantling and removing.

Full particulars from Mr. S. L. PEARCE, Chief Engineer and Manager, Electricity Works, Dickinson Street, Manchester.

Tenders, addressed to the Chairman of the Electricity Committee, must be delivered at the Town Hall, Manchester, not later than 10 a.m., on Wednesday, the 7th April, 1920.

THOMAS HUDSON,
Town Hall, Manchester. Town Clerk.
15th March, 1920. F 302

TYNEMOUTH CORPORATION ELECTRICITY WORKS.

SALE OF STEAM GENERATORS.

The Corporation of the County Borough of Tynemouth are prepared to receive

Offers for the following Plant,

viz:—

Two Holmes-Belliss and One Westinghouse-Belliss STEAM GENERATORS, each of 100 Kw. Direct Current. The Holmes Dynamos are compound wound suitable for from 440 to 550 volts, and the Westinghouse Dynamo is compound wound for 500 to 550 volts.

The Engines are six-cylinder compound for 150 lbs. steam pressure and 100 degrees superheat. They can be converted to triple expansion type, if desired.

The whole of the plant is in first-class condition, and may be inspected, by appointment, at The Electricity Works, Tynemouth. The Corporation are prepared to receive Tenders for the whole or part of the plant, and if desired, they would sell the engines and dynamos separately.

For further details apply to the undersigned.

C. TURNBULL, M.I.E.E.,
Electricity Works,
Tynemouth.
9th March, 1920. F 249

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD (PLANT AND MACHINERY SECTION).

SHIPYARD PLANT.

For Sale by Public Tender,

Lying at
NATIONAL SHIPYARD, CHEPSTOW.

A quantity of High-class SHIPYARD PLANT, including—

PLATE EDGE PLANING MACHINES by Hugh Smith.
COUNTER SINKING MACHINES by John Hetherington & Sons.
MULTIPLE PLATE PUNCHES by De Bergue.
BOGIE and STANDARD type RADIAL DRILLS by Asquith.
SCREWING MACHINES by Joshua Heap, and Kendall & Gent.
SCREW-CUTTING LATHES by Broadbent, and Graham & Normanton.
PLATE-STRAIGHTENING ROLLS by Henry Berry.
WOODWORKING MACHINES by J. Pickles, T. Robinson, T. White & Sons, J. MacDowall, Wadkin & Co., and J. Sagar & Co.
SMITHS' HEARTHS and COPPERSMITHS' FIRES by Alldays & Onions.
AIR COMPRESSORS and MILD STEEL AIR RECEIVERS.

Full particulars and Permits to View, and Tender Forms can be had on application to the CONTROLLER, Plant and Machinery Section, Charing Cross Embankment Buildings, W.C. 2.

Tenders to be lodged not later than 10 a.m., 24th March.

NOTE.—For particulars of other Government Property for Sale, see *Surplus*, price 2d., at all bookstalls; or by quarterly subscription of 2s., post free, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. F 265

THE CARDIFF GAS LIGHT AND COKE COMPANY

Offer For Sale Compressed

AIR AND STOKING MACHINERY by Messrs. West's Gas Improvement Co., Ltd., Manchester, comprising:—

One Two-Stage Air Compressor.
Two Compressed Air Scoop-Charging Machines.
Two Compressed Air Rake-Drawing Machines.
One Simultaneous Charging and Discharging Machine.

These machines are in good running order, well equipped with spare parts, and may be seen in action at the Grangetown Gas Works, Cardiff.

Latest date for receipt of offers, April 19th.

GEORGE CLARRY, F 431
General Manager and Secretary.

TYNE IMPROVEMENT COMMISSION.

HYDRAULIC ACCUMULATOR.

The Tyne Improvement Commissioners invite

Tenders for the Supply and

ERECTION at Albert Edward Dock, North Shields, of a HYDRAULIC ACCUMULATOR.

A copy of the form of Tender, Conditions of Contract and Specification, and a copy of the Drawing, may be obtained from this Office on payment of a deposit of one guinea. The deposit will be returned on receipt of a bona fide Tender.

Tenders in sealed envelopes, endorsed "Tender for Hydraulic Accumulator," to be addressed to the undersigned, and delivered to him not later than Noon on Friday, the 9th April, 1920.

The Commissioners do not bind themselves to accept the lowest or any Tender.

By order,
J. McD. MANSON,
General Manager and Secretary.
Tyne Improvement Commission,
Newcastle-upon-Tyne.
10th March, 1920. F 417

MANCHESTER CORPORATION GAS DEPARTMENT.

TO STEAM LOCOMOTIVE MAKERS.

The Gas Committee are prepared to receive

Tenders for the Supply and

DELIVERY of a SADDLE TANK STEAM LOCOMOTIVE at their Bradford Road Gas Works.

General Specification and Form of Tender may be obtained on application to the Superintendent, Gas Department, Town Hall, Manchester.

Any further particulars and permission to inspect the Sidings may be obtained on application to Mr. WM. NAWROCKI, Engineer, at his office, Rochdale Road Station.

Sealed Tenders, addressed to the Chairman of the Gas Committee and endorsed, "Tender for Locomotive, Bradford Road," must be delivered at the Gas Offices, Town Hall, not later than Five p.m., on Thursday, the 25th March, 1920.

The Gas Committee do not bind themselves to accept the lowest or any Tender.

By Order, THOMAS HUDSON,
Town Hall, Manchester. Town Clerk.
15th March, 1920. F 289

APPOINTMENTS OPEN.

Assistant Master Required

for Works School. Must have had experience in teaching elementary applied maths. and science and machine drawing. Salary £250 to £300, according to qualifications. Replies must be received by March 12th.—Address, THE SUPERINTENDENT, Royal Aircraft Establishment, South Farnborough. D 987

WIGAN AND DISTRICT MINING AND TECHNICAL COLLEGE.

Wanted, Engineering Work-

shop INSTRUCTOR.

Applicants should have good technical knowledge of Engineering as well as wide practical experience in modern workshops.

Initial salary up to £300 according to qualifications and experience. A salary scale in accordance with which increments will be payable is under review.

Further particulars may be obtained from the PRINCIPAL to whom applications should be sent by March 22nd. F 262

LEYTON HIGHER EDUCATION COMMITTEE.

LEYTON TECHNICAL INSTITUTE.

Headmaster: P. J. HALER, B.Sc., A.M.I.Mech.E.

Applications are Invited for

an INSTRUCTOR in Workshop Drawing and other engineering subjects at the Day Engineering and Trade School. Engineering degree or works experience and teaching experience a recommendation. Initial salary from £200 to £275 according to experience. Scale under consideration.

For forms of application send stamped addressed envelope to

R. J. GELDART,
Clerk to the Governors.
Town Hall,
Leyton, E. 10.
March 9th, 1920. F 312

SUNDERLAND EDUCATION COMMITTEE.

JUNIOR TECHNICAL SCHOOL.

Applications are Invited for

the POSITION of MASTER in the above School. Candidates must possess qualifications and teaching experience in Practical Mathematics and Experimental Mechanics, and some practical experience in Engineering.

Salary scale for graduates or those with equivalent qualifications, £180, rising by annual increments of £10 to £220, and then by increments of £15 to £370. Experience (including works experience), up to a maximum of 10 years, will be allowed to count in fixing the initial salary—*e.g.*, with 10 years' approved service the initial salary would be £310.

Forms of application, with three references or testimonials, to be returned to the undersigned by 29th March. The date must be stated on which the applicant could take up the position, if elected.

HERBERT REED,
Chief Education Officer.
Education Offices,
15, John Street, Sunderland.
9th March, 1920. F 294

MANCHESTER MUNICIPAL COLLEGE OF TECHNOLOGY.

Appointment of an Assistant

LECTURER in ELECTRICAL ENGINEERING.

The Governing Body invites applications for an Assistant Lectureship in Electrical Engineering in the College of Technology.

Salary, £340 per annum.

Conditions of appointment and form of application may be obtained from the REGISTRAR, College of Technology, Manchester. The last date for the receipt of applications is Monday, 12th April, 1920.

Canvassing, either directly or indirectly, will disqualify a candidate for appointment. F 422

ROYAL AIR FORCE. BOYS' TRAINING CENTRES.

TEMPORARY APPOINTMENTS ON EDUCATIONAL STAFF.

The Services of a

limited NUMBER of TEACHERS are REQUIRED for duty in the Boys' Training Centres at Halton, near Wendover, Bucks, and at Flowerdown, near Winchester, to give instruction in some or all of the following subjects:—English, Practical Mathematics, Mechanics, Heat and Electricity.

Rate of Salary, £350 to £300, according to qualifications and experience.

Teachers appointed to these temporary posts, whose work is well reported upon, and who have the requisite academic qualifications, will be considered for transfer to the permanent staff as vacancies occur.

Applications giving full particulars in regard to age, education, training and experience, together with copies of recent testimonials, should be forwarded immediately to the SECRETARY (T.3.B), Air Ministry, Kingsway, W.C. 2. F 364

Chartered or other Fully

QUALIFIED ACCOUNTANT WANTED for large Marine Engine Works on North East Coast.—Address, stating qualifications, salary, age, and general experience, F 324, Offices of ENGINEERING.

Assistant Cost Estimator

REQUIRED by boiler department of London engineers; technical training essential.—Address, stating particulars and salary required, F 248, Offices of ENGINEERING.

Wanted, Cost Clerk, Young

Man, 25-30, preferably trained in Engineering Works Office. Must be experienced in modern methods of keeping cost records, wages and material. Cardiff District.—Address, stating age, experience in detail, salary required, F 326, Offices of ENGINEERING.

Rate Fixer.—A Large Engi-

neering concern in the Manchester district, REQUIRE an experienced manufacturing ENGINEER to organise and control rate fixing department. Applications only invited from those who are conversant with latest manufacturing methods of electrical and mechanical details in machining and assembling operations. Good education and tactful disposition indispensable. State age, experience and salary required.—Address, F 350, Offices of ENGINEERING.

An Assistant to the Works

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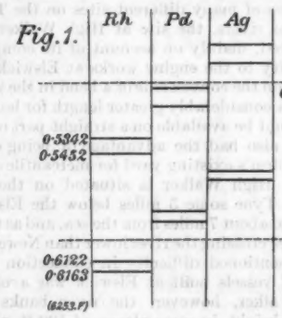
ANALYSIS BY X-RAYS.

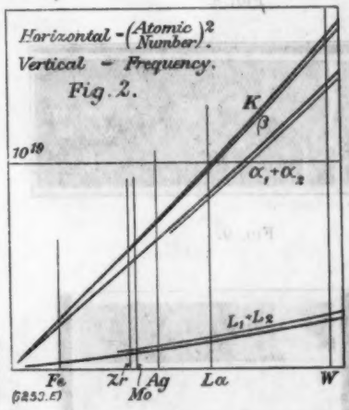
STARTING from the view that the atoms in a crystal are arranged in a kind of three-dimensional grating, M. von Laue in 1912 passed a pencil of X-rays normally through a crystal, backed by a photographic plate, in the hope of obtaining some evidence of the spacing of the atoms in the crystal. The interpretation of the grouping of the dark spots produced on the photographic plate was difficult, and the method seemed to demand the use of crystals the known crystallographic form of which facilitated the deductions. But Laue's collaborators Friedrich and Knipping, as well as the Duc de Broglie, also tried powdered materials.

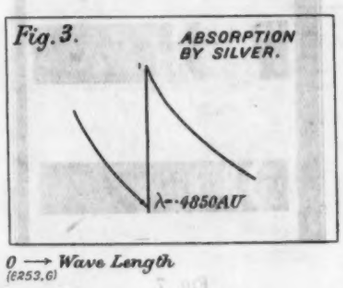
The remarkable successes, however, which Professor W. H. Bragg and his son, Mr. W. L. Bragg, obtained by a more expeditious method, simpler in its calculation—namely, by letting the pencil of monochromatic X-rays fall on a crystal face at grazing incidence so as to be reflected—concentrated attention on crystal analysis by X-rays. But the study of other methods and of powdered materials was not neglected, while parallel with it went the further investigation of X-rays definitely for analytical purposes, and not only in the general interest and for the radiographic examination of living and dead matter. The two main directions in which X-ray analysis has recently developed, were reviewed by Professor W. H. Bragg, F.R.S., when delivering the third Silvanus Thompson Memorial Lecture before the Röntgen Society on March 2, and with this lecture we propose now to deal.



One of the new developments depends upon the greatly-refined methods of distinguishing atom from atom; the other relates to the power of distinguishing crystal from crystal in a conglomerate mass. Both the methods of analysis make use of the X-ray spectrometer, and both the fields differ greatly from those in which light and chemistry are accustomed to operate. The first method is based upon the exact relation found to exist between the atomic number* of an element and the frequency of its X-radiations; the X-rays at once assign any atom, whether separate or part of a compound, to its proper place. To make matters clear, Professor Bragg referred to the case of silver, the atomic number of which is 47. When X-rays longer than 0·4850 AU (1 Angström unit = 10^{-8} cm.) fall upon silver, the metal emits electrons at the same speed. When the primary rays reach this critical wave-length, or become shorter and of still higher frequency, the characteristic rays of the K series of silver are sent out. There are also other characteristic L and M series of longer radiations, but they need not be discussed in this connection. The X-rays of the K series are themselves distinguished as α, β, γ, rays. Very similar K-rays are characteristic of palladium (atomic number 46) and rhodium (45), which are next below silver in the order of atomic numbers, as Fig. 1 indicates. The four main radiations are grouped in the same way, but the whole groups are shifted into the region of greater wave-length as the atomic numbers descend.

In Fig. 2 the ordinates indicate frequency (the frequency 10^{19} is marked), the abscissæ atomic numbers. The atomic numbers of the elements marked are Fe 26, Zr 40, Mo 42, Ag 47, La 57, W74. Different rays are absorbed to different degrees by elements, and the excessive absorption of the characteristic rays is accounted for by their special powers. The wave-length λ 0·4850 of the strong K α line is especially related to silver, as stated. When we try to pass through a sheet of silver X-rays of greater λ, beginning at about $\lambda = 0{\cdot}6$, and gradually shorten the λ, we find that the absorption diminishes and the penetration is facilitated; but at $\lambda = 0{\cdot}4850$ the difficulty of penetration is suddenly increased nearly eightfold, the shorter waves being strongly absorbed. With further diminution of λ the penetration improves again (see Fig. 3). The effect may be displayed in two ways. When we throw an X-ray spectrum (from an anticathode of tungsten, *e.g.*) on a photographic plate, the silver in the emulsion absorbs the waves on the short side of 0·4850 strongly as compared with those on the long side; there is thus greater blackening on the short side, and the edge is sharply defined. When, in the second instance, we interpose a screen of some substance, say, of lanthanum (atomic number 57, special $\lambda = 0{\cdot}3188$), between the bulb and the photographic plate, the waves shorter than 0·3188 will be more highly absorbed, the plate will again show shades of blackening; but this time the chief blackening will be on the long wave side (with respect to the previous blackening). The combination of the two effects gives a band bounded by λ 0·3188 and 0·4850.





Professor Bragg exhibited three such photographs due to M. de Broglie. In the second (which we reproduce in Fig. 4) the screen was antimony (atomic number 51), in the third cadmium (atomic number 48). The first band was wider, the third much narrower, than the band of Fig. 4, and was, in fact, the narrowest possible under the conditions because there is no atomic number between those of silver 47 and cadmium 48. In all the three photographs the silver edge was on the right hand side, because the atomic number of silver is smaller than that of any of the four elements concerned. If the screen had been made of molybdenum (42), the silver edge would be on the left and the molybdenum on the right. The edges are so precise that confusion between atoms cannot arise, even if the absorbing screen be a solution of barium chloride containing only 1 mg. of the salt in the track of the rays, as Broglie observed. If an edge corresponding to an atomic number 43 should be discovered, we should know that it belongs to a still unknown element fitting into the gap between ruthenium 44 and molybdenum 42, one of the several gaps in the sequence of atomic numbers from 1 up to 92.

So far we have dealt with the absorption-band method of X-ray analysis. The second method has been developed mainly by Debye on the Continent and by A. W. Hull and others in America. Professor Bragg, in his lecture, referred particularly to the work of Mr. A. W. Hull, of the Research Department of the General Electric Company (not identical with G. F. Hull who was associated with E. F. Nichols in the radiation pressure verification of 1901). The new method is a modification of the Bragg method, and is applicable, Professor Bragg explained, not only to crystals several millimetres in dimensions, which are not always obtainable, but also to fragments of crystals; one cubic millimetre of material is sufficient to identify any element and compound crystalline in structure. The crystals are completely powdered up, but the fragments are still crystals. They are either loosely compressed to form a thin rod, 2 mm. or 1 mm. in diameter, about 10 mm. long (Debye), or are placed in cylinders of very thin glass or celluloid. When a fine beam of monochromatic X-rays is sent through the substance, it will meet crystals at every orientation, their distribution being entirely at random; it should be so in fact. There will be a certain number of crystals, *e.g.*, whose cubical faces will make the proper angle θ with the incident rays to reflect the particular rays used; they will not reflect any rays at other angles, and in this respect the so-called X-ray reflection—it is not really a reflection—differs from ordinary reflection. Some planes will be in a position to reflect at another angle, and there will be a particular angle for every face. The beam is made to fall on the middle of the rod; the reflected rays will lie on a conical surface and are received on a photographic screen, either on a plane film, on which they produce a system of rings concentric to the spot which the direct beam hits, or on a spherical film curved round that spot. The rings so observed are entirely characteristic of the crystal. No two crystal-forms give the same system of rings, and when the powder is made up of a mixture of different crystals, each will give its own system of rings. In the curved film the rings will appear in the shape of arcs or lines, the photograph looking like a spectrum.

FIG. 4.

It must be borne in mind that these apparent spectra are not spectra in the ordinary sense at all. The rings or lines mark the spacings of the atoms in the crystal. In any crystal the different atoms are placed at the corners of the elementary space lattice, *e.g.*, a cube, or in other definite positions, and we may imagine the atoms to be arranged in an infinite number of planes, the planes of the crystal faces themselves or of their diagonals, or other planes. If there were reflection from all these possible planes, we should not observe any individual lines. But the term "reflected rays" is largely used for convenience and in distinction from the transmitted rays of Laue's first experiments. What we observe is diffraction subject to Bragg's fundamental law, $n\lambda = 2d \sin \theta$, where n is the order of reflection, λ the wave-length of the rays used, d the distance between successive

* A summary of his redeterminations of Röntgen spectra and of Moseley's atomic numbers, from sodium 11 up to uranium 92, was given by Siegbahn in the *Jahrbuch der Radioaktivität u. Elektronik*, vol. 13, pages 296 to 341, September, 1916.

planes of atoms (the spacing), and θ the angle of incidence of the rays. There will be reflection for certain angles: for θ_1 when $n = 1$, for θ_2 when $n = 2$, and so on, and for no other angles, as we have already stated. In his well-known researches Professor Bragg turned the crystal round and observed reflection at certain values of θ, which correspond to definite spacings d; the crystal structure is deduced from three spacings. Professor Bragg explained this with the aid of his space-lattice models of crystals built up of wires and beads; the beads marking the atoms may be at the intersections of wires or at intermediate positions. Holding such a model in the arc beam so that the projection appeared on the screen, he showed that the atoms appear to lie in different parallel lines (representing planes) as the model was turned to face the beam at different angles.

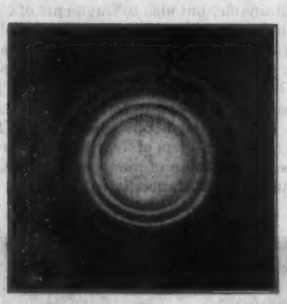


FIG. 5.

FIG. 6.

In our reproduction of some of Hull's photographs exhibited by Professor Bragg, the beam of X-rays was passed either through a circular hole (Fig. 5) or through a slit, and the photographic film was plane or curved (Figs. 7 to 9); in the latter cases only the right half of the picture obtained is shown; the central circular spot, hit by the direct rays, or the slit, appear bright. Fig. 5 illustrates the ring system of aluminium. The small tube of glass or celluloid was filled with fine filings of pure aluminium and was exposed for 3 hours to molybdenum X-rays (at 40,000 volts and 9 milliampères) filtered through zircon powder; the two inner bright rings shown are at deviations $2\theta = 17{\cdot}8$ deg. and $20{\cdot}6$ deg. respectively. The spacings characterise a face-centred cube, side length $4{\cdot}05$ A.U.

The iron used in obtaining the result shown in Fig. 6 was electrolytic or reduced from oxide; both gave identical patterns indicating also a face-centred cube of side-length $2{\cdot}86$ A.U. The photograph, Fig. 7, of electrolytic magnesium, required an exposure of 6 hours; the lattice is hexagonal.

As regards diamond, the various methods of Laue, Bragg, Hull and others are in close agreement; in our issue of December 7, 1917, page 594, we referred to the work of Debye, who concluded that graphite and amorphous carbon have the same structure, and that there are hence only two (not three) allotropic modifications of carbon. Professor Bragg did not dwell upon this point, but exhibited the Hull photographs of diamond and graphite (see Fig. 7); on the diamond photograph, 27 lines can be counted, just as many as there ought to be. If X-rays of rhodium had been used (instead of the molybdenum rays), the number would be 30.

Our last two illustrations, namely, Figs. 8 and 9, exemplify the analysis of alkali salt mixtures. All the halogen compounds of sodium and potassium crystallise in colourless cubes, and in mixtures or minerals containing both the elements it is very difficult to settle even by quantitative analysis whether we are dealing with (NaCl + KF) or with (KCl + NaF), especially in the presence of other alkali salts which would affect the proportions. The photographs, Figs. 8 and 9, and others exhibited by Professor Bragg make this distinction possible. Sodium chloride Na shows certain lines and no others; KF, NaF, KCl, each have their own lines. When any one of these salts is present in a mixture, the whole of its lines is seen, and as we have in special cases to look out particularly for certain impurities, we are provided with a new method of analysing mixtures and of testing for impurities.

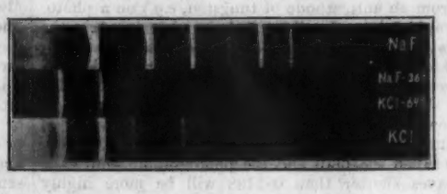


FIG. 8.

FIG. 9.

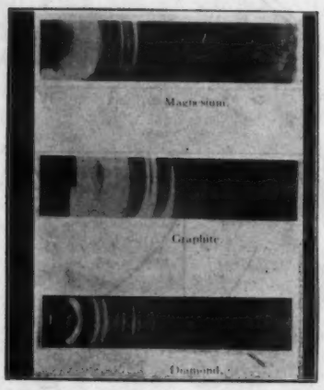


FIG. 7.

The method does not look easy; the differences are not striking, and the lines of Figs. 8 and 9 are, of course, not lines of the elements, but lines indicating spacings; the coincidences of certain lines are mere chance. Yet we have in the case of some alloys and minerals hardly any means of ascertaining whether the carbon, *e.g.*, is present free or as a carbide of one of the several possible metals, so that this radiographic method may become as valuable to metallurgists and mineralogists as the X-rays have already proved in testing metals for flaws and in other respects. To radiologists the method is not difficult, and the long exposures may probably be shortened. So far nothing seems to have been done with alloys. But no promising method is neglected at the present time, and at the meeting of the Röntgen Society, those present were very grateful to Professor Bragg for having dealt with so difficult a subject in such a lucid manner, worthy of the great man in whose honour the lecture was delivered.

THE ARMSTRONG SHIPYARD.

IN the summer of 1914, in connection with the Naval Architects' Congress held that year in Newcastle, we published* a brief general description of what was then known as the Armstrong Naval Shipbuilding Yard at High Walker-on-Tyne, promising to give a full account of the construction and equipment of the yard at a later date. The outbreak of the war, only a few weeks after the publication of the article referred to, prevented us from redeeming our promise until now, but as the subject has rather grown than diminished in interest during the interval of nearly six years, the unavoidable delay which has occurred is not without its compensating features. As previously explained the yard was intended mainly for warship work, and it was laid down on account of the fact that the distance between the piers of the swing bridge at Newcastle set a limit on the beam of vessels that could be constructed at the Elswick yard of the firm, Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited. More room was also required at Elswick for the extension of the Steel Works, Engine Works and other departments, and this fact also influenced the firm's decision to carry on their shipbuilding work elsewhere.

After considering the relative advantages and disadvantages of many different sites on the Tyne, and on other rivers, the site at High Walker was finally selected, mainly on account of its comparative proximity to the engine works at Elswick and its situation on the convex side of a bend in the river, which gave a considerably greater length for launching than would be available on a straight part of the stream. It also had the advantage of being quite close to the firm's existing yard for mercantile work at Walker. High Walker is situated on the left bank of the Tyne some 5 miles below the Elswick shipyard, and about 7 miles from the sea, and as there are no bridges crossing the river lower than Newcastle the above-mentioned difficulty in connection with the beam of vessels built at Elswick was avoided. At High Walker, however, the river banks rise steeply to a height, in some places, of 130 ft. above the quay, so that a large amount of excavation work was necessary to reduce the site to a convenient level. On the site selected there existed two small factories, a village, and a number of old thoroughfares and new roads, the acquisition of which necessitated somewhat protracted negotiations, but on the completion of these, at the end of 1910, the work of excavating the site was immediately put in hand.

The total area of the site amounts to 83 acres, and, as shown in the key plan, Fig. 1, on page 367, it is bounded on the western side by a branch line of the North-Eastern Railway, which here runs approximately parallel with the river. The line is about 68 ft. above the quay level, and, consequently, it was necessary to use a considerable area of land in forming slopes on which railway lines would be laid for bringing materials down to the yard. The key plan shows that these slopes were made at the north-west corner of the site. They are wide enough, in one part, to take four lines of sidings, and the gradients are in no case steeper than 1 in 30. Other land had, of course, to be occupied by an embankment sloping from the yard level to the higher ground, the average vertical height of this embankment being about 100 ft. The actual levelled area of the yard thus amounts to about 50 acres, but by further excavation at the southern end of the site the levelled area can still be extended if necessary.

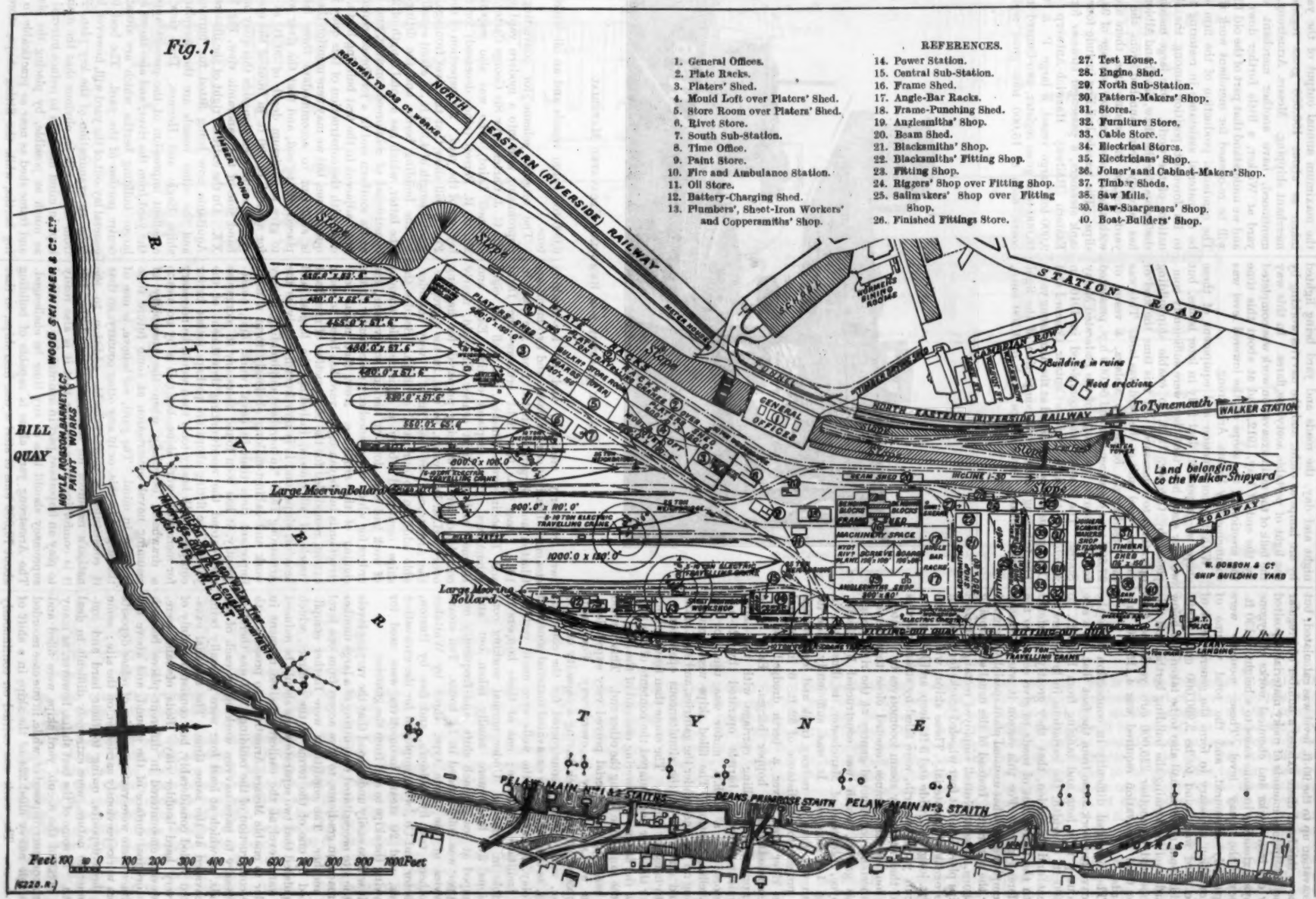
The excavation work which, as previously mentioned, was commenced towards the end of 1910, was entrusted to Messrs. Edmund Nuttall and Co., of Trafford Park, Manchester, and the appearance of the site at the time of the commencement of the work is shown by the panoramic view reproduced in Fig. 2, on Plate XX. This view was taken from the river on November 1, 1910. After a careful survey of the site had been made, 75 section lines were set out between the river and the railway at distances of 50 ft. apart, with intermediate lines where the nature of the surface rendered them necessary. From these sections the volume of the

* See ENGINEERING Vol. xcviii. page 1.

THE ARMSTRONG SHIPBUILDING YARD OF SIR W. G. ARMSTRONG, WHITWORTH AND CO., LTD.

(*For Description, see opposite Page.*)

Fig.1.



excavation up to the 90-ft. level was calculated; but above this level there existed a number of irregular and precipitous mounds of rocky material deposited by old iron works and chemical works of bygone days, extending in some cases to a height of 130 ft. above the quay level. These mounds were separately contoured, and the total volume of excavation necessary to form the general level of the yard was found to be 3,890,000 cub. yards. Additional material had also to be taken out below yard level for forming the building berths, and this amounted to another 225,000 cub. yards, so that the total excavation required was 4,115,000 cub. yards.

The principal difficulty in connection with the excavation work arose from the fact that, on a site about ¾ mile long and ranging from 1,200 ft. to 1,500 ft. in width, the variations in level were so great and so sudden, that they greatly interfered with the laying out of roads to give access to the different parts. For this reason it was necessary to employ somewhat unusual plant specially designed for the contract. Instead of the usual side-tipping wagons, Messrs. Nuttall employed rectangular steel skips placed on flat four-wheeled trucks for handling the excavated material. These skips, which were 12 ft. long, 7 ft. wide and 3 ft. deep, and held about 8 cub. yards of earth, were filled by steam navvies and then drawn by steam locomotives to a battery of four electric cranes, erected close together on a specially constructed gantry at the river's edge. This gantry, which was constructed by Messrs. Royce, Limited, of Manchester, is illustrated in Fig. 1A, annexed. It was sufficiently wide to span two lines of railway track and long enough to project for a distance of 32 ft. 6 in. beyond the river wall, over a berth dredged for the accommodation of hopper barges. Each crane comprised a travelling carriage with two independent hoisting barrels operated by 25-h.p. motors, and a 10-h.p. motor was used for the travelling motion. The filled skips were brought along on the lines under the gantries, and each crane lifted one skip by the simultaneous operation of both hoisting barrels. The crane then travelled out over the river and dumped the contents of the skip into the hopper by lowering one end of the skip and at the same time lifting the other end. This method of handling the material proved very expeditious, and was satisfactory in every way. Four self-propelled hoppers, each having a capacity of 1,500 tons, were specially constructed for the contract, and, as the bulk of the excavated material consisted of clay, the sides of the wells were made vertical to facilitate discharge; one of these hoppers is visible in Fig. 1A. Under normal working conditions five loads were usually taken out and dumped at sea in each shift, and frequently one hopper was fully loaded in 1¼ hours. Ten steam navvies of the crane type, three by Whitaker Brothers, two by Wilson's, and five by Ruston, Proctor and Co., were employed for the excavation work, and 20 steam locomotives were used for drawing the skips to and from the gantries.

It will be easily understood that the varying levels of the site necessitated the cutting of a large number of roads on gradients, to give access from one level to another. The conditions were further complicated by one of the terms of the contract, which stipulated that two separate areas should be reduced to yard level at the earliest possible moment in order to enable Messrs. Armstrong to proceed with the construction of the buildings. It was therefore necessary to have navvies working on each of the levels, of which at least four were generally being excavated at the same time. The material excavated varied considerably, but consisted mainly of a very hard boulder clay. Beds of sand were, however, encountered in different places beneath the original surface of the ground, and above the surface there were vast quantities of refuse deposits from works previously carried on on the site; some of these deposits, owing to their hard and conglomerate nature, were extremely difficult to deal with. In some of the best shifts, however, as many as 1,083 of the 8 cub. yard skips were filled and their contents disposed of, while, in one case recorded a single navvy filled 224 of the skips in a shift of 10 hours. The work was carried on continuously night and day, the roads and yard being lighted by arc lamps at night, and the navvies working by the light of portable acetylene flares. In this way the bulk of the main excavation work was completed by the end of May, 1912, and at about this time the erection of the shops on the lowered level was commenced by Messrs. Armstrong.

With the construction and equipment of these shops we propose to deal fully in later issues, but we may state here that they were sufficiently completed by October, 1913, to enable shipbuilding operations to commence. At this time the keel of the first vessel built at the yard was laid. This was the Dreadnought battleship Malaya, a vessel of 27,500 tons displacement and 56,000 h.p., presented to the nation by the people of the Federated Malay States. The Malaya was completed in 1916, in which year the light cruisers Centaur, Concord and Courageous were also finished at the Armstrong yard. The following year saw the completion of the light cruiser Furious, eight sloops (each of 1,300 tons), two train-ferry steamers, and an ice-breaking steamer. The light cruiser Danae and two monitors, Glatton and Gorgon emanated from the yard in 1918. Last year two light cruisers—the Delhi and Dunedin—were finished, as well as eight submarines. The seaplane carriers Eagle and Hermes and the light cruiser Emerald, nearly completed, are now being prepared for handing over to H.M. Dockyards, so that, in the aggregate, the Armstrong yard has made a very considerable addition to our naval strength. Besides the ships mentioned above a considerable amount of work had been done on various war vessels, the orders for which were cancelled subsequently to the signing of the armistice. Now that naval construction is in abeyance, the yard has been, to some extent, remodelled for the construction of merchant vessels of all classes, including the largest and heaviest ships, and it is now known simply as the Armstrong Yard. In merchant shipbuilding, joinery work and cabinet-making obviously form a more important item than in naval work, and, consequently, it has been found necessary to reorganise and extend the woodworking department of the yard. The fitting shops are perhaps rather better equipped with heavy tools than would be necessary for mercantile work alone, but this is by no means a drawback, especially when the possibility of resuming naval construction at some future time is borne in mind. The yard, we believe, is one of the largest in this, or in any other country, so that it constitutes a most valuable addition to the nation's resources for merchant shipbuilding, but it is comforting to remember that it is also ready to play an important part in maintaining our naval supremacy should this at any time be challenged. The Armstrong yard alone is capable of building about 70,000 tons of steel a year into ships, so that the maximum annual output of the yard may be taken as about 100,000 gross register tons of merchant shipping. Messrs. Armstrong, as already mentioned, have another merchant shipbuilding yard at Walker, a little further down the Tyne, and we understand that part of the old Elswick yard will be re-opened for merchant work if necessary. The combined production of the firm should thus be of material assistance in restoring the country to its foremost position among the shipbuilding nations of the world. One large merchant vessel, the Tairoa, for the Shaw, Savill and Albion Company, has already been launched from the Armstrong yard, and, at the present time, there are 13 vessels with a total gross register tonnage of 95,000 on the slips. The vessels building include four 10,000-ton tank steamers, a passenger steamer for the Great Eastern Railway Harwich-Antwerp service, a 9,000-ton cargo vessel, a large P. & O. liner of 16,000 tons gross register, two Cunard intermediate boats, each of 15,000 tons gross register, three 6,000-ton cargo vessels and an oil tanker of 8,000 tons.

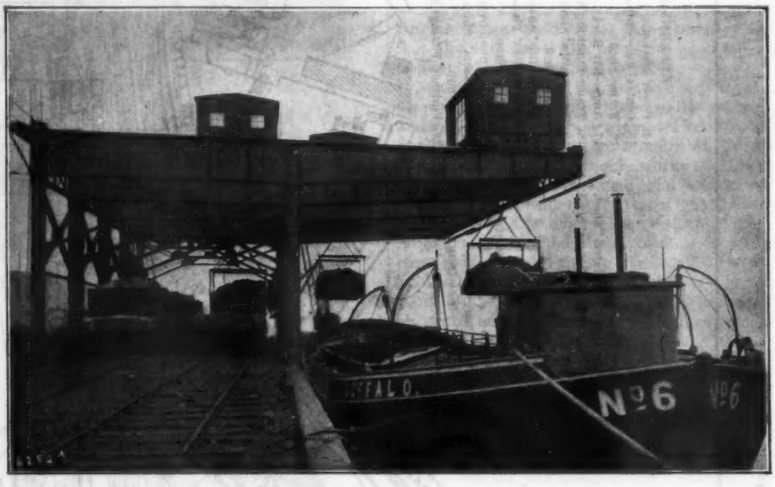
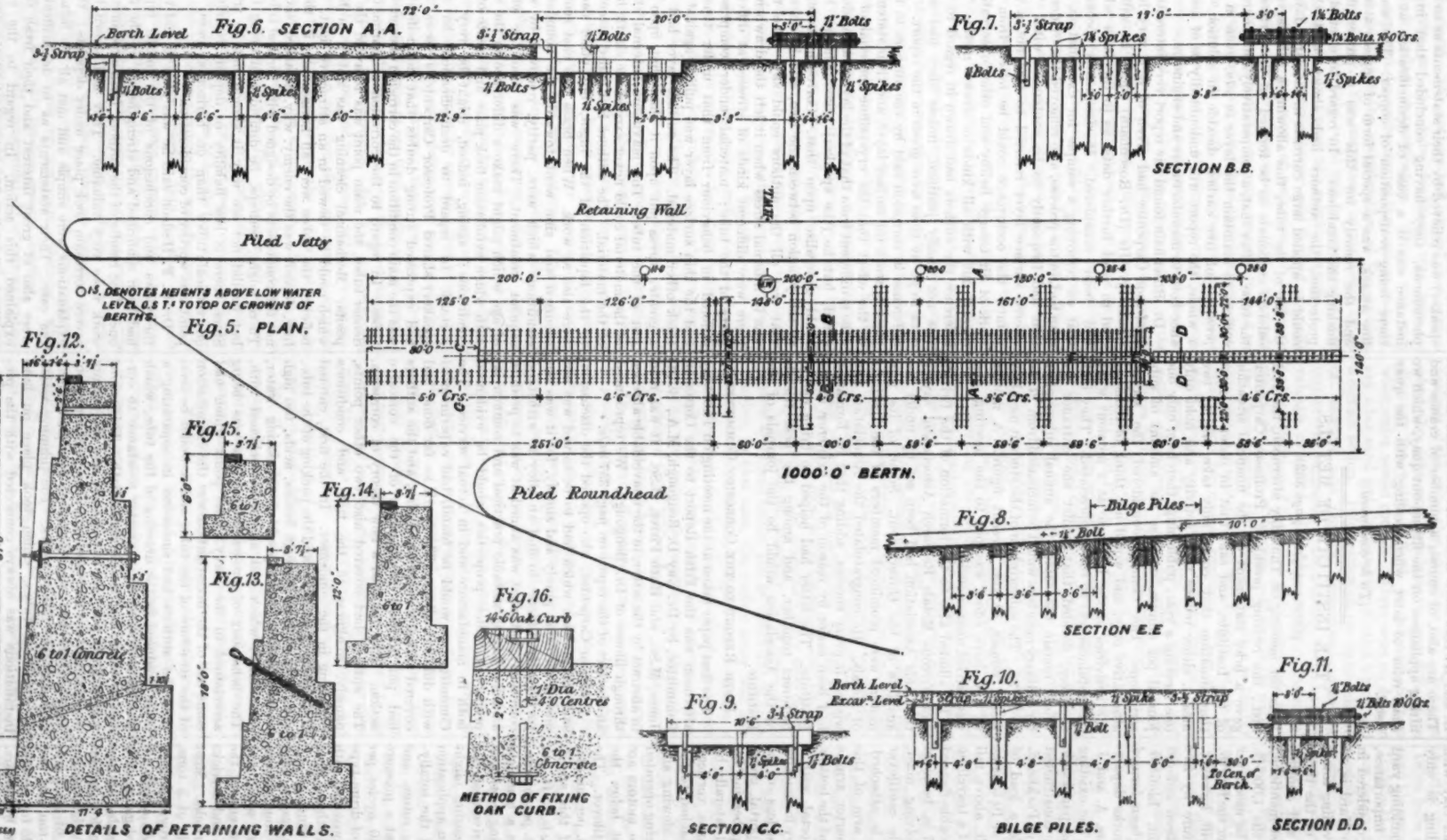


Fig. 1A. Gantry for Removing Excavated Material.

The original scheme for converting such an unpromising site into a modern yard was due to Mr. G. J. Carter (now Sir George Carter, of Messrs. Cammell Laird), who was also responsible with Mr. J. R. Perrett (since deceased) for the general lay-out of the yard. An inspection of the key plan, Fig. 1, will show that the river frontage, which has a total length of 4,350 ft., is about equally occupied by the building berths and the fitting-out quay. The latter, which has a total length of 2,133 ft., is constructed of reinforced concrete, and terminates at its southern end in a reinforced concrete round-head adjacent to the first building berth. We shall deal with the construction of this quay in a subsequent issue, but we may here mention that its length is sufficient to accommodate three large vessels placed end to end, and that the river was dredged to give a minimum depth of 30 ft. at low water for a width of 100 ft. in front of the quay. Three vessels can be seen alongside this quay on the right-hand side of the panoramic view, Fig. 3, on Plate XX. On the extreme right of the illustration is the Aquitania now being fitted for burning oil fuel, and the other vessels are the aeroplane-carrying ships Eagle and Hermes. This view gives an excellent impression of the present appearance of the yard from the river, and also shows some of the larger building berths which are situated in the centre portion of the yard. The best idea of the general lay-out of the yard will, however, be obtained from an examination of the key plan, Fig. 1, and from this it will be obvious that the main principle kept in mind has been to reduce internal transport, as much as possible, by placing the platers' shed and frame shed as near as practicable to the building berths, while the fitting shops, stores, joiners'

THE ARMSTRONG YARD: 1,000-FT. SHIPBUILDING BERTH.



shops and other departments mainly engaged on work on vessels after launching, are kept close to the fitting-out quay.

As originally laid out, the yard was provided with nine building berths, but another berth has since been added at the southern end, and the other berths in that vicinity have been increased in breadth so that the smallest can now accommodate a cargo vessel of over 10,000 tons deadweight. The largest berth is of sufficient size to allow of the construction of a vessel 1,000 ft. in length with a beam of 120 ft. Adjoining this is a berth capable of taking a vessel 900 ft. long by 110 ft. beam, and the next berth can take a ship 800 ft. long by 100 ft. beam. The maximum dimensions of vessels that can be built on the seven remaining berths are all shown on the key plan. A panoramic view of the largest berths, taken from the roof of the mould loft, is reproduced in Fig. 4, on Plate XX, and it is perhaps hardly necessary to explain that the apparent distortion is due to the fact that the illustration is made up of four photographs taken separately, and afterwards joined up. The illustration also shows the travelling tower cranes with which these berths are served.

The three largest berths were designed for battleship construction, and were therefore specially strengthened by timber piling, so that they are quite suitable for the construction of the largest and heaviest merchant vessels yet contemplated. The construction of the largest berth, and the arrangement of the piling is illustrated by the drawings reproduced in Figs. 5 to 16, on the present page. The left-hand side of this berth (looking towards the river) is formed by the fitting-out quay and the piled roundhead previously mentioned. On the other side, between the 1,000-ft. berth and the adjacent 900-ft. berth, is a jetty formed at its upper end by two concrete retaining walls with a hard-core filling between them, while below high-water level the jetty is constructed of reinforced concrete. The reinforced concrete portion of the jetty, which is clearly shown in Fig. 3, on Plate XX, is 350 ft. in length, and the retaining walls extend for 467 ft. on the inner side and for 290 ft. on the side adjacent to the 900-ft. berth. The jetty is 30 ft. wide at the top for the whole of its length. Sections of the retaining walls are given in Figs. 12 to 15, while Fig. 16 illustrates the method of fixing an oak curb on the edge; but it will be convenient to deal with the reinforced concrete part of these structures with other work of a similar nature in a later article. This berth, it will be noticed, has a total width of 140 ft., and the ground slopes uniformly towards the river at an inclination of 1 in. 25. Two rows of piles were driven close to the centre line to carry the keel blocks, and others on each side to take the launching ways. Groups of bilge piles were also driven at approximately 60 ft. intervals in the central portion of the berth. The general arrangement and spacing of all the piles, which are of pitch pine and of 14 in. by 14 in. section, is clearly shown by the plan and sections, Figs. 5 to 11. The next two berths are of similar design and construction, and have similar jetties between them, but the seven

smaller berths are all arranged on one uniform grade and are not piled. The subsoil of all the berths, it may be mentioned, is a hard boulder clay with good bearing properties, so that piling is only necessary for the very heaviest work.

The crane equipment of a large shipbuilding yard is obviously a matter of the utmost importance, and this question was very carefully considered in laying out the Armstrong Yard. The Yard is, at present, equipped with four electric travelling tower cranes, one of which is kept on each of the three jetties between the first four berths and another works on the fitting-out quay. The last-mentioned can, however, be brought alongside the 1,000-ft. berth, so that two of these cranes can be used over each of the first three berths and one over the fourth. The facilities for handling materials will, however, be greatly increased in the near future by five additional tower cranes which have been ordered from Messrs. Armstrongs and Main, Limited. This firm, it may be mentioned, has been formed by the amalgamation of the engine works department of the Armstrong firm with Messrs. A. and J. Main and Co., Limited, of Glasgow. The existing cranes, all of which are visible in the panoramic views, Figs. 3 and 4, on Plate XX, were constructed by Sir William Arrol and Co., Limited, of Parkhead, Glasgow, and are designed to handle a load of 5 tons at a radius of 120 ft. and a load of 10 tons at a radius of 60 ft. A clear lift of 90 ft. above rail level is obtained. The cranes consist of a travelling tower structure mounted on eight double-flanged wheels running on rails laid at 26 ft. 6 in. between centres. The tower supports a revolving mast, to the upper end of which a double cantilever structure, of the over-trussed type, is attached. The load trolley runs on the longer arm of this cantilever, and at the end of the shorter arm a balance weight is placed. The bracing at the bottom of the tower is arranged to form a portal, with a clear height of 30 ft., so that the ordinary locomotive jib cranes can pass easily between the legs of the tower cranes. Immediately over the portal, cross-girders are fitted to carry the footstep bearing for the revolving mast, which is supported laterally by large cast steel rollers with their axes vertical, working inside a circular steel ring attached to the top of the tower. Hoisting, racking, slewing and travelling motions are provided, each being operated by an independent motor, and all the motors are controlled from a cabin situated just below the inner end of the longer arm of the cantilever. The hoisting speed for a 5-ton load is 100 ft. per minute, and a 10-ton load is hoisted at half this speed. The racking speed, with a 10-ton load, is 75 ft. per minute, and the travelling speed is 80 ft. per minute. In slewing, the cantilever arm makes a complete revolution in 2 minutes, and the slewing motion is fitted with a special form of friction drive designed to absorb the shock to which the gearing might otherwise be subjected by a too sudden application of the brake. The motors are all of the totally-enclosed reversing type with slip-ring rotors, and are designed for three-phase current at a pressure of 440 volts and a periodicity of 40 cycles per second; they are operated by means of drum-type reversing controllers. The cranes are provided with brakes and anchor chains to prevent them from being blown along the track by a high wind.

In addition to the travelling tower cranes, each of the large berths is provided with four electric winches with blocks and tackle for shell work, and the six smaller berths at the southern end of the yard are each equipped with 10 masts and derricks with one electric winch for every two derricks. Most of the derricks are intended for loads of 3 tons, but 5-ton and 12-ton winches are provided here and there for specially heavy lifts. As shown on the key plan, Fig. 1, a line of standard-gauge rails is laid between each of the smaller berths, and on this line 10-ton steam cranes can run for general work. Seven of these 10-ton steam locomotive cranes are employed in various parts of the yard, and there are also one 7-ton, three 5-ton and two 3-ton cranes of a similar type, available for general use; most of these cranes were made by Messrs. Thomas Smith and Sons (Rodley), Limited, of Rodley. One large shunting locomotive, and four crane locomotives, capable of lifting 3 tons at the end of the jib and 5 tons at a smaller radius, are also employed in the yard; the latter are of Messrs. R. and W. Hawthorn Leslie and Co.'s manufacture. There are also, of course, a number of cranes and lifting appliances on the fitting-out quay, which we shall refer to later when dealing with the quay itself.

(To be continued.)

THE INSTITUTE OF METALS.

(Continued from page 352)

AT the meeting on Thursday afternoon, the 11th inst., the retiring president, Professor Carpenter, gave a brief statement on the financial situation of the Institute, and said that in order to meet that situation they could only take one of two means, either reduce their activity and hold only one meeting a year, publishing, therefore, only one journal per annum, or raise the amount of subscriptions. The Council considered the second alternative only, and would not think of reducing the activities of the Institute at a moment when its usefulness was so fully appreciated. They had, therefore, decided that whilst the entrance fee would remain the same, the annual subscription for ordinary members would be increased from 2*l.* 2*s.* to 3*l.* 3*s.* The subscription of the student members would remain at the present figure. A motion to the above effect was put to the meeting, and was carried unanimously.

He alluded also to the formation of the British Non-Ferrous Metals Research Association, saying that this Association had been set up under the auspices of the Government. Some of its promoters were prominent members of the Institute of Metals. He congratulated the Association and wished it every success, adding that its formation had been easier by reason of the existence of the Institute. The latter had helped to bring manufacturers together, and among the best friends of the Association would be the journals of the Institute.

FIFTH REPORT TO THE CORROSION COMMITTEE.

The first paper taken at the meeting on Thursday afternoon was the Fifth Report to the Corrosion Committee, by Dr. Guy D. Bengough, M.A., R. M. Jones, M.Sc., and Ruth Pirret, B.Sc. It was read in abstract by the latter, in the unavoidable absence through illness of Dr. Bengough. We reproduced an abstract of the report on page 357 *ante*.

Professor Carpenter, who opened the discussion, said the problem which had to be solved was not one of corrosion purely and simply, for it was not particularly difficult to find an alloy to withstand corrosion; but what was aimed at was to produce an alloy having suitable practical and commercial properties, which properties would be evidenced both in manufacture and in actual service. The Committee, it would be found, had experimented with different alloys. The work so far done had covered alloys of copper and zinc, and the authors had put forward a diagnosis of the corrosive action. This involved a new theory of corrosion. The authors had covered also two other points, namely, weakness in the tube and conditions operating in the condenser. In the first, entered the quality of the alloy and the packing of the tube, and, in the second, foreign bodies, acids, too high a temperature, and speed of circulating water, possibilities which had all to be reckoned with. The behaviour of pre-oxidised tubes was being ascertained in the Navy. One point which had come out of the investigation was the examination of the structure of the tube, and it would be seen that the authors had succeeded in separating a layer produced in the drawing of the tube, which was characterised by a greater resistance to corrosion than the metal underneath. This point was of great practical importance, and the feature would make for a decrease in the chances of corrosion. The authors had also described five phenomena and also gave five remedies. The thinning action in condenser tubes, which took place on land installations was always connected with the presence of acids. The difficulty in marine machinery was deposit attack, and the remedy there was simple theoretically; it resolved itself into keeping the tubes clean. The types of dezincification to which the authors called attention, formed, perhaps, the most important part of the report, and he (the speaker) was relieved by their statements as to this phenomena, they having concluded that in no instance was it a case of dezincification at all, there being re-deposition of copper. The water-line attack was a special form of deposit attack, and the remedy for this was a proper flow, flushing the condenser. In regard to electrolytic protection, the authors had shown that there could be applied large currents in the early days of the life of the tube, this allowing a thin layer of calcium carbonate to be formed on the surface of the tube; after that, a comparatively small current suffices to maintain the layer *in situ*, even in the presence of free carbon dioxide in solution. As a whole, the report will undoubtedly be of assistance both to manufacturers and engineers.

Dr. Rosenhain found the report very interesting; Professor Carpenter had given of it a very lucid summary. He (Dr. Rosenhain) added he will be glad to read further data as to the facts which had been considered. It frequently occurred that on removing a sample for examination, the man had, in the process, also removed the evidence; that had frequently to be contended with. The altered surface layer referred to was not a new point; the occurrence could be noted from the work of Sir George Beilby and other observations carried out with all kinds of drawn metal. The inference the authors had drawn in regard to this was not finally justified, unless they had more data to go by than were given in the report. The difference in corrosion said by the authors to take place beneath the surface layer, and their statement to the effect that the crystalline material of the tube is different from that of the layer, can no doubt stand, but he (the speaker) asked whether they could generalise upon that. Corrosion occurred at the junction between the two, and he thought that was all the authors could say. The tube was in internal stress when it left the drawbench; there were different kinds of stresses at different parts of the tube; material under compression differed in behaviour from that under tension, and the thin surface layer was pulling against the thick other material. The surface layer had had a greater stress put upon it than that upon the rest of the tube. The maximum internal stress of the material could never exceed the elastic limit of the material. The authors had called attention to the liquation of the ingot, but other causes were also at work. When brass was cast scoring occurred and zinc went towards the boundaries, conditions which were, partly, removed by subsequent treatment. There was also the effect of age which might make a difference in the ease with which exfoliation took place and create other conditions; ageing, indeed, might be very important. In regard to dezincification, he (the speaker) shared Professor Carpenter's views, and had expressed strong doubts that dezincification was the main condition in the corrosion of condenser tubes. In regard to the corrosion of marine condenser tubes, the main point was to avoid the deposits. Mechanical cleaning was not a problem which could be viewed in an attractive light. He believed the tubes were all horizontal; if, therefore, deposit was the enemy, why, he asked, should not the condensers be designed with vertical tubes? There might, perhaps, be difficulty in doing this, but he did not see why it should not be tried. Since there is less liability of deposit remaining on vertical tubes than on horizontal ones, the point was worthy of consideration.

Dr. O. F. Hudson said he was glad to find that the views and conclusions of the fourth report had been confirmed and strengthened by the fifth one. The results of the authors' fresh experimental work were very valuable. They had shown how severe corrosion took place under deposits; their explanations were simple and met all the facts of the case. Their statements as to dezincification were also of great interest and their fresh data explained this action. In regard to the slow uniform action along the tube, the initiating causes were external to the tube, except dezincification, and "dezincification" was the only severe type of

corrosion in pure sea-water. The actual start of this action was not yet quite clear; it seemed to be associated with a particular property of the tube itself. The authors had shown that neutral deposits on the tube localised this type of attack called dezincification. There was only an apparent dezincification as the authors had said, and this made the consideration of the problem more simple. The importance of the action of deposits on the tube could not be exaggerated, and particularly any deposit of a colloidal nature.

Mr. F. de Würstenberger said he had specially studied the question of corrosion of condenser tubes since the commencement of 1915. He made his first experiments on pure copper, instead of on brass, and soon ascertained that the dezincification theory was wrong, the corrosion phenomena being as characteristic of copper as rust is of iron. There may be found many parallels between the two. He was glad to see that the present views of the corrosion committee as to dezincification were in conformity with his own. He soon gave up experiments with cupric chloride, $CuCl_2$, as he soon found that by solutions of copper in any chloride liquid, either with or without electrolysis, there was always the cuprous salt CuCl, which formed first and which never changed into cupric chloride, $CuCl_2$, except only under the influence of air into the cupric oxychloride, a quite insoluble salt. The study of the qualities of the cuprous chloride, CuCl, had revealed the most interesting explanations of the phenomenon. A point in regard to which he differed entirely from the views stated in the fifth report was that his experiments induced him to put electrolytic action in a neutral solution absolutely in the first place in comparison with any pure chemical action, to which, however, he attributed an important influence in changing the electrolytic potentials of the areas on whose surfaces they took place. He might say it was undoubtedly impossible that pitting throughout a tube 1 mm. thick, occurring in about two weeks in common and even very pure sea-water, could be explained by pure chemical action. On the other hand, he produced pitting quite similar to that in condensers, in the course of a few days, with electric currents of very low voltage, say only some tenths of a volt, in slightly alkaline water. In an alkaline solution (ammonia solution always excepted) tubes covered with a layer more or less electrically insulating, so that the greater part of the tube was protected and a current of low voltage found its outlet into the liquid at some spots only where, through either chemical or mechanical action, the insulating film was destroyed. There pitting was produced, and this explained the absolute irregularity in its happening. He had detected lately such currents in a condenser plant in France. As a preventive means he preferred to shut off the source of such currents rather than create counter electro-motive forces by so-called protectors. Protective electro-motive forces were always of a more or less unstable nature; there was the risk that certain parts were at one time anodic and at another time cathodic areas, which were the most dangerous conditions for corrosion. He had experimental proof that copper and brass corroded in normal sea-water, even in the complete absence of exterior currents; but in this case the action was again an electro-chemical one which occurred between areas covered on the surface of the metal with layers of different potentials. The difference of potential may be caused by a depolarisation, either by mechanical means, by great water velocity or by the springing off of pieces of brittle layers, or, again, by chemical means through the transformation of the original cuprous chloride into another insoluble salt such as, for instance, cuprous oxide, the process taking place under the influence of heat, or increase in alkalinity by the stagnation of the water, or the carrying along of cathodic products. The explanation of the so-called "deposit attack" was to be looked for in such action of local increased alkalinity. Acids or ammonia solutions, when present, may only produce general thinning.

Mr. R. T. Rolfe congratulated the authors for their valuable contribution to the subject of corrosion. They had given a very clear explanation of the reputed phenomenon dezincification, and he suggested that in future this should be known as copper-deposition. He called attention to the remissness in sending researchers complete data and analysis of the water that came into play. But even when the data were available it was difficult to diagnose the water, difficult to tell the engineer what water would corrode. There were no data to say what sand and the quantity of sand which had a certain action. Information on the water, chemical analysis and physical properties—suspension matter—he suggested to the authors, would be very valuable to record. It was not so much the metal as the condition of the water which came into play, such as the action of deposits, sediment in the water. He asked whether the authors had come to further conclusions in regard to the best material for use for general and for marine purposes. There was, he might mention, a tube on the market for which the most far-reaching claims were made in the matter of corrosion, and he asked whether the authors had done anything with that tube.

Admiral Goodwin congratulated the authors and especially Miss Pirret, who had given an excellent abstract of the report. He agreed that the report contained a great deal of information on the possible and probable causes of corrosion. But there was still work to be done, and it would have to be carried out until all doubts could be removed and no further trouble occurred. He was glad to see the recommendations as to the information which was asked for concerning the water supply and the corroded tubes, information which was demanded as complete as possible. That information had been acted upon by the Admiralty for years past. The returns from individual ships were similar in many respects to that detailed in the report. The navy had been puzzled to find the real cause for corrosion in several particular cases where trouble had occurred, for it was difficult to follow the matter up. He (the speaker) wanted to know more about the suface layer referred to in the report. The Admiralty tubes were drawn from a cast shell, of, generally, 70–30 brass, turned outside and bored inside, and he would like to know whether, in that case, the surface layer was also formed. The Admiralty's object was to secure a smooth surface on the tube, one which would not attract deposits; but besides that smooth surface did they also secure the surface layer the authors had referred to? With reference to the placing of vertical tubes in condensers, a suggestion put forward by Dr. Rosenhain, if vertical tubes could be resorted to probably deposits would be reduced; but in ships one was handicapped in reference to space. He (the speaker) would, however, look into the matter, although he was rather afraid the innovation would not be possible. The report had given practical recommendations to follow, and in some lines of steamers that could be done, but not in the navy in many instances, for a ship was obliged to steam probably from the White Sea to the tropics, when all conditions, such as temperatures and others, varied immediately. One method could not be maintained on a man-of-war for any long period. Here Admiral Goodwin put in a communication from Engineer-Commander Dunlop, who referred to the possibility of seaweed giving rise to trouble by stopping the inlets and otherwise, and causing any amount of mischief. Commander Dunlop thought that if particles of seaweed hung up in the tubes, corrosion would follow at a rapid pace.

Mr. R. M. Jones, in replying briefly to the discussion, thanked the members for their appreciative remarks, and was glad that so many of the speakers were at one with them (the authors) with regard to dezincification being only apparent. He agreed with Mr. Rolfe in the advisability of parting with the term and using instead, "re-deposition of copper." When one got the so-called dezincification there occurred a sharp boundary between the copper and the brass, and no gradual passing from the pure copper to the corroded brass. In the matter of the schedule of information required, he agreed the authors were asking for a large amount, but in a standardised investigation there was not much difficulty in arriving at the information, and he was glad to hear from Admiral Goodwin that the navy reports were on the authors' practice. With regard to the surface layer, the authors were inclined to be not very sanguine relatively to the rates of corrosion which took place; all the specimens tested and stripped of the surface layer were half tubes. Referring to Admiral Goodwin's remarks bearing on the Admiralty practice of obtaining the tubes from a shell turned outside and bored inside, and his query as to the presence or not of the surface layer in that case, he said that so far the authors had not detected any difference between the Admiralty and the 70–30 brass tubes. He was glad to hear the particulars of Mr. de Würstenberger's independent investigations on condenser tubes, and would be glad to have access to his paper before he made any comments on these investigations; but he noted that Mr. de Wurstenberger found pitting so rapid that chemical action could not account for it. He (the speaker) did not think it was quite as rapid as made out, and did not agree that cupric chloride was formed from the cuprous chloride. The authors, he added, would deal fully with the discussion in the Journal.

The Action on Aluminium of Hard Industrial Waters.

The next paper taken was on "The Action on Aluminium of Hard Industrial Waters," by Richard Seligman, Ph.D., and Percy Williams, B.Sc. We reproduced it on page 362 *ante*. It was read in abstract by Dr. Seligman, who said they had not given any measurements as they did not think measurements were of any use. They did not separate theory from practice, but gave a clear description of the occurrences, and stated the views arrived at.

Dr. O. F. Hudson appreciated the value of the authors' results and conclusions. He had not made an extensive study of this particular aspect of the corrosion problem; his own paper, written in collaboration with Dr. Bengough, on aluminium corrosion in sea-water dealt with a research that was carried out with a definite object, and this particular work had been discontinued, but it was gratifying to find the agreement which existed between the present authors and Dr. Bengough and himself. He was much interested in the authors' statement that a difference of potential in the metal was relatively unimportant in stimulating corrosion, and he agreed with them. The authors' explanations of the blistering of aluminium sheets were of great interest. Hydrogen peroxide, they said, played an important part; this also occurred in the corrosion of zinc. He was not quite clear as to how the hydrogen peroxide acted, and he asked the authors whether they could give their views more fully on that point, and as to how hydrogen peroxide set up corrosion. This was, no doubt, a deal to ask, because the point was a difficult one to arrive at. In regard to the presence of aluminium oxide and the part played by minute cavities, the action was quite likely the one suggested. But blistering could occur where the surface layer happened to be punctured, when action might spring inwards, giving rise to the blistering. The authors had found that hydrogen peroxide was a harmful corrosion agent, and he asked them as to the presence or absence of free acid in their tests. He was glad to read their paragraph as to observation of results (reproduced on page 363 *ante*), and he agreed with their views. Loss of weight experiments were useless and misleading in many instances.

Mr. R. M. Jones said that the local action set up underneath the deposits, referred to by the authors gave strong support to the fifth report of the Corrosion Committee, where it dealt with the pitting of brass. In regard to the authors' views on the electrolytic action, they had found the same occurrence with brass; at the strained parts of brass they did not find centres for that action. The work on brass by the Corrosion Committee and the authors' researches with aluminium were largely complementary.

Admiral Goodwin stated that the discussion would be dealt with in detail by written communications to the Journal. The authors' paper was one from which a large amount of information would be gathered.

Autumn and May Meetings.

On the members reassembling on the morning of Friday the 12th inst., the chairman, Admiral Goodwin, announced that the Council had not yet completed their negotiations in the matter of the

forthcoming autumn meeting. They hoped, however, to be able to announce in a few weeks the place and date of the said meeting. He further stated that the next "May meeting" would take place this year on June 10, when Dr. Benedicks would deliver the tenth May lecture, his subject being "Recent Progress in Thermo-Electricity."

THE ART OF CASTING IN HIGH TENSILE BRASS.

The first paper taken on Friday was on "The Art of Casting in High Tensile Brass," by W. Neil J. Maclean, who read it in abstract. We reproduce the paper on page 388. In this, the author said that manganese bronze castings as supplied by different makers having proved unreliable and unsatisfactory, a series of experiments was carried out with a view to obtaining castings made in sand moulds, unchilled, having a guaranteed strength of not less than 20 tons per square inch, as shown by test bars produced under the same conditions as the castings themselves. As a result of these experiments a copper zinc alloy was chosen containing 3 per cent. of nickel and 2 per cent. of iron, with a small quantity of manganese and phosphor-tin. Special precautions were taken to accurately weigh the charge and to control the pouring temperature within narrow limits. A hardener of copper nickel-iron was made up and finely granulated by blowing the molten metal into a tank of water. Special attention was paid to keeping the zinc content constant; ingots were analysed after first melting and the zinc corrected when making up the final charge. The alloy finally decided upon was made up of scrap, new metal, and a hardener, with the addition of zinc to correct for loss in previous melting. By the accurate weighing of the charge, control of pouring temperature, correction of zinc, and use of a special hardener, castings were obtained having strength properties 50 per cent. better than gun-metal and at a lower price.

The discussion was opened by Mr. H. B. Weeks, who referred to the author's statement to the effect that there was still a gap between the application to daily routine work in the foundry of the knowledge gained by the scientist in a laboratory, and until that gap could be bridged improvements shown in laboratory experiments could not be realised in practice. This statement would be viewed with satisfaction by all the practical members, many of whom felt that they had not perhaps received fair dealing; this might possibly be their own fault. He, personally, would not decry the academical side of the questions, for academical work had been of great use. The author's paper could be read in conjunction with the president's address of the day before. Similar experience to that of the author's had been obtained by all who manufactured castings. He might add that the paper came 25 years too late; 25 years ago he had had the same experience as the author's with brass containing nickel. He had then made manganese bronze which he had exposed to the action of the atmosphere, when the iron it contained led to rusting. He afterwards made an alloy containing not more than 2 per cent. of nickel, which gave excellent physical results. It was used by the Admiralty for a long time until the overseer at Barrow found it had too white a tint. He then took up the manufacture adding iron, when it was always difficult to get the tests. It was not difficult, however, to get the tests from a manipulated bar, or from one taken from a given part of the casting; they could not be obtained say with a bar taken from the header, but they could from one taken from a propeller blade. These various questions as to the suitable manufacture of castings were questions for co-operation between engineers and metallurgists; they also covered the suitable training of apprentices and foundrymen. An ideal foundryman would be one able to design the piece required, make the pattern for it, make the mould and carry out the casting. He had, so far, only met one man who could do that, and he was a Swiss; he seldom had any failure; he knew the behaviour of the metal throughout, where exactly to put the risers and so forth. The next best means in the absence of such a capable man would be for all who had the best experience on the subject to co-operate.

Mr. R. T. Rolfe found the paper an essentially practical one which would prove greatly useful, but thought the author had not been quite fair to gun-metal, for the figures he had quoted, 14 tons ultimate strength, 7 tons elastic limit and 7·5 per cent. elongation in 2 ins. were not standard figures. In ordinary runs far better results than these could be obtained. His (the speaker's) own results on sand castings of various weights showed an average of 15·6 tons and 10·6 tons, and 12·6 per cent. respectively. There were many reasons why gun-metal was so largely used, to the exclusion of high tensile brasses, one of them being that we had to work to specifications. In sea-water, also, the behaviour of gun-metal was better. In the fifth report of the Corrosion Committee it could be seen that in corrosion tests gun-metal showed better results than brass and high zinc alloys, all of which latter corroded more and behaved generally less well than gun-metal. Another reason was that the other, high tension, alloys had a much higher shrinkage than gun-metal, and required larger gates.

Mr. O. W. Ellis said he found the bronzes referred to in the paper had shown an extremely low ultimate strength. He had made many tests before the war of manganese bronze and had obtained results varying from 25 tons to 35 tons, and a very low elongation. On looking into the matter, he found that the order in which the ingredients were put in the crucible had an important bearing on the point. He then obtained results giving 45·8 tons tensile, 27 tons elastic limit, and 30 per cent. elongation, and on the actual castings 44 tons, 27 tons, and 20 to 28 per cent. elongation. These figures were those both of their own testing machine and of the one at Woolwich Arsenal. He had also tried cadmium, but like the author he found it made no difference and disappeared. An addition of 0·33 per cent. of lead made a great difference in the tensile strength, which dropped by about 14 tons. An addition of 40 per cent. to 60 per cent. of scrap made no difference, but at the third melt the addition of runners and risers led to a deterioration of the metal. In regard to the obtaining of test bars, there ought to be some final arrangement arrived at; he (the speaker) could obtain any result wanted if he were allowed to place the test bar where he liked.

Admiral Goodwin said it had been asked why gun-metal were not abandoned and high tensile brass adopted in its stead; the latter was adopted for many purposes, but gun-metal, also, had been found a good servant, and before it was discarded it must be made certain that the other alloy was as good for any special applications. There was to be considered the behaviour in sea-water, the obtaining of as good castings, the behaviour at high temperatures, the machining, &c. If all these points were answered satisfactorily consideration would be given to the question.

Mr. Maclean, in his reply, said the chairman had answered the queries as to the use of either gun-metal and high tensile brasses; a number of difficulties did not occur in land installations, where the latter brasses could be resorted to. In regard to the figures of physical tests, a distinction had to be drawn between the guaranteed strength and the average one; there was a great difference between them. The lowest figure for gun-metal was the one given in the paper. He was carrying out the development of educational work, by classes which were being arranged for. An alloy in which scrap could not be introduced was not an advantage, for scrap was produced in somewhat large quantities and it had to be utilised.

(To be continued.)

HONGKONG TRADE.—The Colonial Report on Hongkong says *Indian Engineering*, states that the world-wide shortage of mercantile shipping has had a marked effect upon the trade of the colony which is almost entirely dependent upon ships for its prosperity. Decreases in the imports of oil (23,536 tons), coal (371,325 tons) and cotton (23,556 tons) are put down to this cause. The imports showed an increase in the cases of liquid fuel (24,979 tons) and sugar (115,423 tons). Refined sugar was in great demand in China and the Persian Gulf, but here again business was restricted by the shortage of tonnage. The year was favourable for cement manufacturers, demand continuing to be good. Trade has also suffered by the political chaos existing in China. The statistical position of trade in most goods, however, is sound, and with settled conditions the prospects of business would be encouraging.

THE MOTOR-BOAT EXHIBITION AT OLYMPIA.

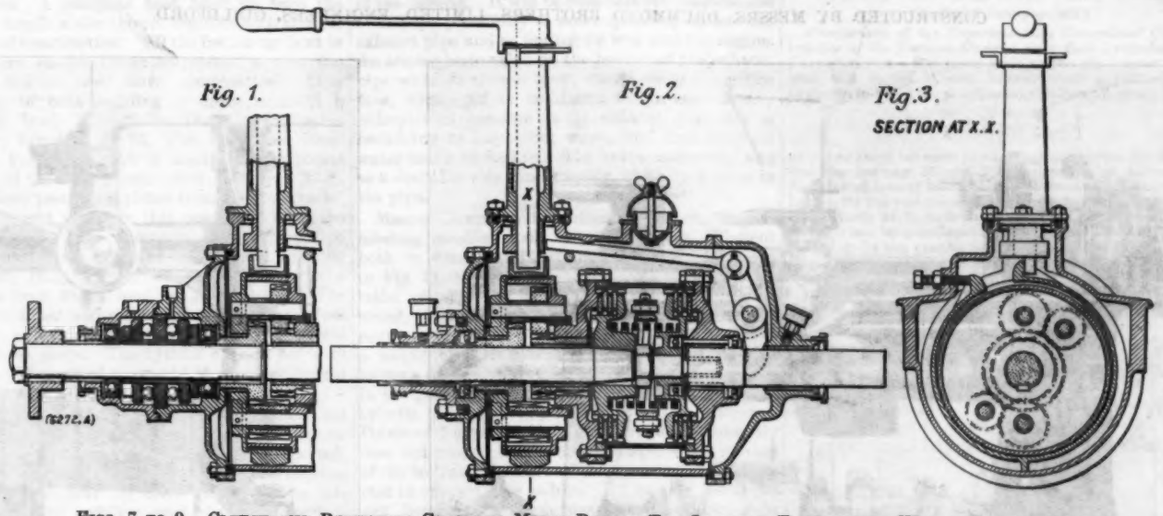
No Motor Boat Show has been held at Olympia since March, 1914, but the intervening years have seen the internal combustion engine called upon to bear responsibilities upon the sea at least comparable with those it was entrusted with on land and in the air. Hence these years have been a period of active development of the marine motor-industry, yet the growth has been one rather of magnitude than of evolution, for before the war the general design of motors had settled down along lines which do not seem likely to alter much so long as the reciprocating engine holds the field. The motor Boat and Marine and Stationary Engine Exhibition which was opened at Olympia on March 12, bears out the above statements for the war does not appear to have left its mark upon any of the exhibits except, perhaps, in connection with minor details. It must, however, be added that certain of the exhibits could never have appeared but for the war, and notably the famous coastal motor boat, C.M.B. 4 on Messrs. Thornycroft's stand. With a true instinct for the fitness of things the boat is exhibited in exactly the condition in which she came home from the Baltic after repeated passages on various errands through the lines of forts guarding the Russian capital, and finally, torpedoing the Bolshevik cruiser Oleg. For his exploits in command of the C.M.B. 4 it will be remembered that Lieutenant Agar, R.N., was awarded a well-earned V.C.

The boat in question seems to be the principal attraction of the show for the general public judging by the queue of persons always waiting their turn to mount the platform whence her interior can be seen. The C.M.B. 4 is a skimmer or hydroplane of the type invented by Sir John Thornycroft, and developed by him before the war for sporting purposes. The craft is 40 ft. long on the waterline, with a beam of 8 ft. 6 in., and is fitted with a 12-cylinder V type Thornycroft engine of 225 b.h.p., giving a speed of 40 knots when carrying full armament, fuel and crew. The torpedo is discharged over the stern, or alternatively, to a torpedo, three 450 lb. depth charges can be launched. Lewis guns provide still further offensive power. Adjoining the C.M.B. 4 is an excellent aerial photograph of Cronstadt Harbour taken by the R.A.F., showing the Bolshevik warships at anchor there. The day after the photograph was taken a small flotilla of C.M.B.'s entered the harbour and destroyed all the effective units of this fleet. The exhibit is in connection with a scheme for raising funds for the Overseas Relief Fund of the Navy League, which should benefit materially from the enterprise.

Reverting to exhibits of a nature more typical of the show, one is struck by the important place which the crude oil engine of the semi-Diesel type is taking in connection with marine propulsion. There is a general family resemblance among all representatives of the type, just as there is between the various makes of high speed internal combustion motors; but details have as yet hardly reached an equal uniformity. In view of the fact that the hot-bulb heavy oil engine is of British origin, it is regrettable that its development for marine purposes has been left so largely in the hands of Continental engineers. Several of the leading British firms, however, such as Messrs. The Ailsa Craig Motor Company, Limited, W. H. Allen, Son and Co., Limited, William Beardmore and Co., Limited, Norris, Henty and Gardner, Limited, David Joy and Collis, Limited, Robey and Co., Limited, and Vickers-Petter, Limited, all of whom are well known either as steam or oil engine builders, are now turning out marine crude oil engines of British design. The Kromhout engine has, of course, been manufactured in this country for several years, and Messrs. Babcock and Wilcox have recently purchased the designs of a Swedish engine, which will be known as the Babcock and Wilcox Munktell engine. Several of these engines, of Swedish manufacture, ranging up to 100 b.h.p., are on view at their stand.

Among the exhibits of the firms mentioned above all of which are worth examination by those interested in the crude oil engine, some of those on the stand of Messrs. William Beardmore and Co., Limited, of Dalmuir, are particularly interesting, as

EXHIBITS AT THE MOTOR-BOAT SHOW AT OLYMPIA.



FIGS. 7 TO 9. CLUTCH AND REVERSING GEAR FOR MOTOR-BOATS; THE LANGDON ENGINEERING WORKS, SOUTHAMPTON.

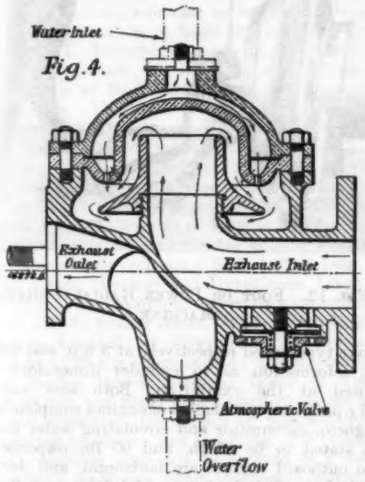
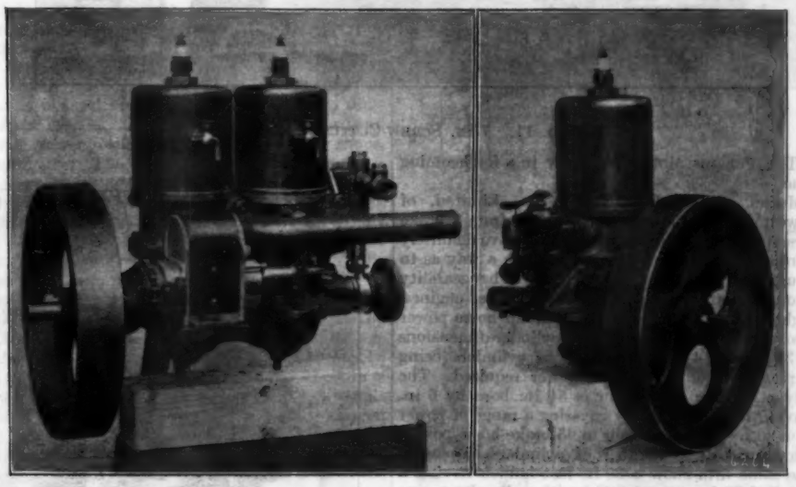


FIG. 10. LANGDON'S EJECTOR SILENCER.



FIGS. 5 AND 6. SIX H.P. AND THREE H.P. ENGINES; MESSRS. W. D. FAIR AND CO., HAMPTON WICK.

details of some of the larger engines being built by this firm are exhibited separately. Among these are parts of the special 480 b.h.p. engine now under construction for the British Imperial Antarctic Expedition ship, the Terra Nova. The bedplate, crankcases and cylinders of a 320 b.h.p. engine are also shown separately, besides a three-throw crankshaft and a stern tube, shaft and propeller for an 80 h.p. engine. Contrasting with these heavy engines the same firm also show a 160 b.h.p. Beardmore aero-engine utilised for commercial purposes by being coupled to a D.C. interpole generator, through a gear reducing the engine speed of 1250 r.p.m. to the dynamo speed of 625 r.p.m.

Messrs. Perman and Co., Limited, 82 and 83, Fenchurch-street, E.C.3, show three British Kromhout engines, two of which rated respectively, at 90 b.h.p. and 26 b.h.p., are for marine propulsion, while the third, rated at 8 b.h.p., forms the motive power of an oil-driven cargo winch. The largest of the engines is illustrated in Fig. 1 on page 380. Like all of its type it works on the two cycle valveless system. The cylinders are $13\frac{3}{16}$ in. bore by $13\frac{3}{4}$ in. stroke, and the unit is complete with reverse gear, bilge pump, &c. Fig. 2 shows the general appearance of the cargo winch which is capable of lifting 15 cwt. at a speed of 100 ft. per min. The special features of these engines are the absence of the usual type of hot bulb in the cylinder head, which is always liable to be a source of trouble, and the elimination of any water injection. Crude oil having a flash point between 130 deg. F. and 200 deg. F. is used as fuel, the consumption under test conditions being about 0·58 pint per b.h.p. hour. Owing to the particular design of the combustion chamber it is possible to run these engines under any conditions of load without the necessity of using the starting blow-lamp, and after several hours running at no load, full load may be taken with equal ease. We may mention that the manufacture of the British Kromhout engine has now been taken up by Messrs. Day and Summers, Limited, of Southampton, who, having their own shipyards adjoining their engine works, are naturally in an unusually favourable situation for installing them in either new or existing boats.

In addition to the British exhibitors of crude oil engines whose names have already been mentioned, visitors to the Motor Boat Show should also inspect the stands of Messrs. James Pollock, Sons and Co., Limited, of 3, Lloyd's-avenue, E.C.3, who are the British representatives of the J. and C. G. Bolinders Company, Limited, of Stockholm, and exhibit both large and small engines made by the latter firm. The Oil Power Company, of 39, Victoria-street, W.C., show specimens of the "Avance" engines, also of Swedish manufacture, Mr. Arthur R. Brown, of 54, New Broad-street, E.C., shows small engines made by the N.V. Machinefabriek "Bolnes," of Holland, and other makers are also represented.

The exhibitors of the smaller motors, constructed on the lines of the motor car engine, are so numerous and the productions generally of so high merit that it is somewhat invidious to mention names. For marine purposes paraffin or kerosene is, of course, almost universally used in preference to petrol. The Parsons Motor Company, Limited, of Southampton, who were one of the earliest firms to manufacture a successful paraffin engine have a very fine display, which includes many applications of their engines to purposes other than propelling boats. Two 60 brake horse-power Parsons engines are shown, one direct coupled to a dynamo, and the other to a centrifugal pump. The latter set is specially arranged for salvage work, and includes a small exhausting pump for getting the centrifugal to pick up its suction. A 21 h.p. engine is arranged to drive two cylinder single stage air-compressor on the same bedplate, a speed reduction gear being incorporated with the drive. The appearance of this set mounted on a bedplate as a self-contained unit, complete with radiator, air-receiver, &c., is illustrated in Fig. 3, page 380. It is specially intended for use in shipyards in connection with pneumatic riveters, acetylene welders, &c. Fig. 4, on the same page, shows a three-cylinder Parsons paraffin engine driving a 12 k.w. dynamo at 900 revolutions per minute, by means of a flexible pin coupling. The cylinders of the engine are $4\frac{1}{2}$ in. bore by 6 in. stroke. Such sets are supplied largely for small or emergency electric lighting plant. We shall publish drawings and fuller details of some of the products

EXHIBITS AT THE MOTOR-BOAT SHOW AT OLYMPIA.

CONSTRUCTED BY MESSRS. DRUMMOND BROTHERS, LIMITED, ENGINEERS, GUILDFORD.

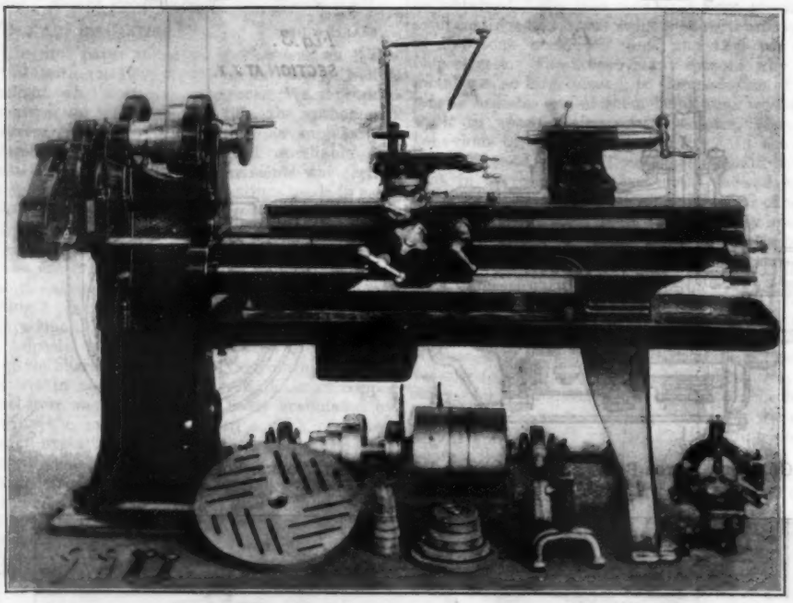


FIG. 11. 7-IN. SCREW-CUTTING LATHE.

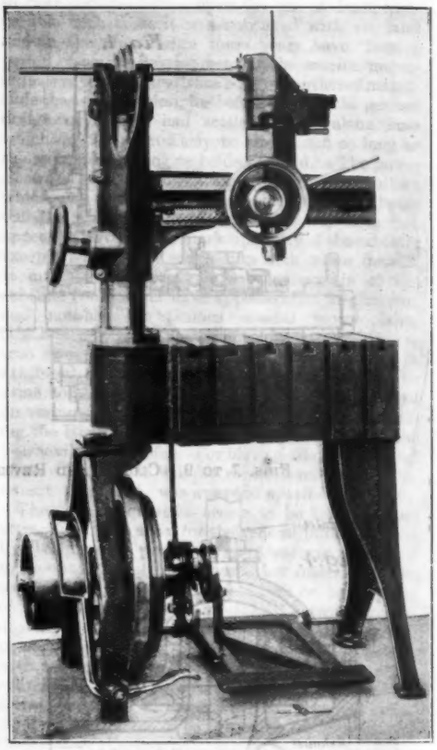


FIG. 12. FOOT OR POWER RADIAL DRILLING MACHINE.

of The Parsons Motor Company in a forthcoming issue.

Messrs. J. W. Brooke and Co., Limited, of Lowestoft, who show engines ranging from 8 brake horse-power to 65 brake horse-power, have definitely standardised their productions in such a way as to secure the maximum degree of interchangeability among corresponding parts of different-sized engines. Eight brake horse-power to 30 brake horse-power is covered by engines all having cylinder dimensions of 3½ in. by 4½ in., one to four cylinders being employed according to the power required. The only other size of cylinder is 5½ in. bore by 6 in. stroke, this size similarly covering a range of power from 20 brake horse-power to 65 brake horse-power, according to the number of cylinders employed. The same firm show a 30-ft. fast launch having a speed of 20 knots and fitted with a Brooke engine with electric starter. Also a 25-ft. standard teak launch of 10½ knots speed, for use in the tropics and a 16-ft. standard mahogany dinghy with a speed of 6 knots.

The Aster Engineering Company, Limited, of Wembley, Middlesex, show many of their engines, adapted either for marine propulsion or for electric power purpose. These, however, are well known, and have already been illustrated and described in our columns. The same remark applies to the sets shown by Messrs. John I. Thornycroft and Co., Limited, of Basingstoke and Southampton, Messrs. W. H. Allen, Sons and Co., Limited, and several other firms. The largest paraffin engine, built on what may be called standard motor lines, which we noticed, was a Djinn engine, built by the Commercial and Marine Engine Company, Limited, of Church-road, Hanwell, London, W. 7. This is rated at 90 brake horse-power at 550 revolutions, and has six cylinders, each 6½ in. bore by 8½ in. stroke. This type is built to the order of the Marine Branch of the R.A.F. A two cylinder engine of the same bore and stroke, rated at 30 brake horse-power, is on the stand, as well as other engines of various sizes. Almost as large as the Djinn engine, is the 75 brake horse-power paraffin engine of Messrs. Gleniffer Motors, Limited, of Anniesland, Glasgow. This has six cylinders, cast in pairs, each being 6 in. bore by 8 in. stroke. A six-cylinder engine of similar dimensions, but rated at 60 brake horse-power at 550 r.p.m. is shown by the Atlantic Land and Marine Engine Company, Limited, of

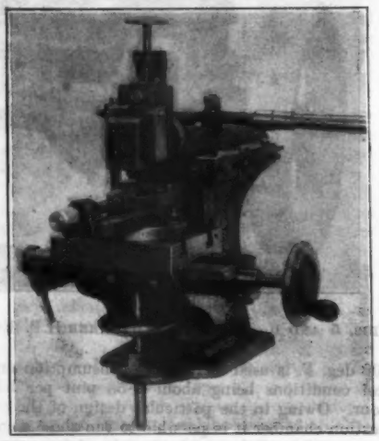


FIG. 13. HAND SHAPING MACHINE.

Wishaw, N.B., together with many smaller ones. Space, however, will not permit even a summary of the more or less standard engines exhibited at the show.

Some firms are specialising in the provision of small auxiliary motors for rowing boats and other very light craft, and appear to vary in their ideas as to how best to solve the problem very much in the same way as the manufacturers who have undertaken the somewhat corresponding one of applying auxiliary power to the pedal cycle. Messrs. Walter D. Fair and Co., of Pembroke Works, Hampton Wick, Middlesex, are making auxiliary motors of from 2 brake horse-power to 12 brake horse-power, some to be fitted inboard, more or less in the ordinary way, and some constructed so that the whole of the power unit, propeller, &c., can be attached to the stern of the boat without structural alterations. Two of Messrs. Fair's motors for installation inboard, we illustrate in Figs. 5 and 6 on page 373. They are entirely self-contained and adequately protected. The engines are of the two-stroke type, rated respectively at 3 h.p. and 6 h.p., but information as to cylinder dimensions was refused at the exhibition. Both sets run at 800 r.p.m., and the weights of engines complete with magneto, carburettor and circulating water pump, are stated to be 50 lb. and 90 lb. respectively. The outboard engines are horizontal, and drive a vertical crankshaft from which the propeller is driven by bevel gear. The whole of the shaft and gear is neatly housed in a brass tube. The weight of the crankshaft is taken by a ball thrust below the crank, and the drive for the magneto is provided for by means of another set of bevel gear above the crank. The engine being of the two-stroke type, there are no valves to be driven. Occupying no space in the boat, and of extreme simplicity of operation, the outboard attachment of Messrs. Fair, should be a useful adjunct. The engine, which is said to develop 3 h.p. to 4 h.p. at 900 revolutions, forms, with the propeller and steering gear, a complete detachable power unit, weighing less than 100 lb. A smaller pattern rated at 2 h.p. to 3 h.p., and weighing about 60 lb., is also made. The name "Watermota," which has been given to the engines mentioned, should not deter visitors from examining them. Outboard attachments are also exhibited by other firms, such as the Evinrude Motor Company (England), Limited, 107, Waterloo-road, S.E.; the Knight Outboard Motor Company, Limited, of Riverside Hampton Wick, Kingston-on-Thames; and the Geo. H. Gascoigne Company, of 3, Central Buildings, Westminster, &c., who all show apparatus of the type.

The application of mass production to boats, with its necessary standardisation of manufacture, is of American origin, on which Continent the sawn timber, together with the exact quantities of fittings, nails and screws to build a standard house, has long been a common article of commerce. The Whitehead Timber Sales Company, of 88, Leadenhall-street, London, E.C., is developing the industry of

standard boat-building in this country, and is exhibiting the woodwork required to construct a 10-ft. dinghy crated ready for shipment to the place of erection. A complete boat built up from the standard details is also shown, together with another in course of construction. All the frames are bent to the required shapes before shipment, so that the amateur builder need have comparatively little knowledge of boat building in order to make a successful boat. The K.D. Boat and Engine Company, Limited, of 25, The Foreshore, Scarborough, Yorkshire, show a much more elaborate specimen of the same construction, namely, a 35-ft. cabin cruiser partly completed from standard parts. The component pieces in this case come from the United States. The company are prepared to supply standardised details of framing and planking for vessels ranging from an 18-ft. launch to a passenger boat 68 ft. long by 14 ft. beam. The frames are fitted and erected at the factory before shipment, and the planking is dressed to thickness and sawn to shape. The system enables boats to be sent to all parts of the world at very low freight cost.

Besides these standardised boats, which are interesting chiefly owing to their method of construction, there are at Olympia, as may be expected, a large number of motor launches, boats and cruisers which are attractive for other reasons. The size of some of the exhibits and the corresponding difficulty and expense of transporting them to the building is striking evidence as to the seriousness with which the show is taken by manufacturers. Messrs. J. I. Thornycroft and Co., Limited, of Southampton, show, for instance, a 45-ft. motor cabin cruiser of the seagoing type, fitted up with great luxury. The vessel has a beam of 8 ft. 9 in., a draught of 2 ft. 7½ in., and a speed of 12½ knots. Motive power is provided by an engine capable of developing 70 h.p. on petrol, and fuel tanks carrying 65 gallons are carried on both sides of the boat. The engine is situated right forward. The firm are constructing a number of boats of this type and are able to give delivery for the coming summer. Other fine-looking craft are a 50-ft. launch built by Messrs. Dixon Brothers and Hutchinson, Limited, of Woolston, Southampton, driven by a six-cylinder engine, a 40-ft. cruiser shown by The Green Engine Company, Limited, of Edwin-road, Twickenham, driven by a 100-h.p. Green engine; a 26-ft. standard ship's towing launch built to Board of Trade requirements, and fitted with a Gardner engine and Marconi apparatus, the launch in question being constructed by Messrs. Cox and King, of Wivenhoe, Essex. Mention must not be omitted of a cabin cruiser built by Messrs. Short Brothers, Limited, of Rochester and Bedford. This is a seagoing craft, 30 ft. long, with an 8-ft. 6-in. beam and a midships depth of 6 ft. 1 in. It is capable of going round the British Isles or to the Continent with ample accommodation for two persons.

There are many types of clutches and reversing gears for marine motors at Olympia. We illustrate, in Figs. 7 to 9 on page 373, that manufactured and exhibited by The Langdon Engineering Works, Northam, Southampton. When the controlling lever is in the "ahead" position, the drive takes place through the medium of two independent friction clutches, which automatically tighten themselves as the torque increases by means of a roller and cam action, the mechanism of which will be understood from the illustrations. When the ahead drive is in action there is no strain on the teeth of the epicyclic gear which comes into operation when going astern. The whole of the mechanism is enclosed and runs in oil. The Langdon Company have standardised clutches and reverse gear of this type up to 150 brake horse-power, at 800 revolutions, but build larger sizes when required. The same firm are exhibiting specimens of their ejector silencer for motor boats, illustrations of which we give in Fig. 10, page 373. It will be seen that the cooling water from the engine enters the centre of the cover of the silencer and flows down over a dome shaped projection, escaping from the chamber by means of a number of small holes around the base of the dome. The exhaust of the engine strikes the inner surface of the dome, and is turned back into an annular space where it comes in contact with the finely-divided water, by which it is reduced in volume and temperature. Any excess of water escapes by the outlet at the bottom of the casting. It will be seen that the construction avoids the possibility of water splashing up into the exhaust pipe and so finding its way into the engine. An atmospheric valve on the bottom of the exhaust pipe which is always open, except when the engine fires, allows air to be drawn in, in case of any reduction of pressure in the exhaust pipe, due to backfiring or any other cause, and thus prevents water being sucked in. The valve, moreover, acts as a drain for any condensation which may occur in the pipe.

Messrs. Drummond Brothers, Limited, are exhibiting machine tools of various types, excellent both in design and workmanship. We illustrate in Fig. 11, on page 374, their latest type of S.S.S. lathe, of which an example is to be seen on their stand. The lathe illustrated has 7½ in. height of centres with a 6-ft. bed. It will admit work having a length of 3 ft. 9 in. between centres, and will swing a diameter of 9½ in. over the saddle, or 21 in. in the gap. Like all modern lathes it has a hollow spindle, the latter being bored out to 1½ in. diameter. Points of design which the photograph unfortunately does not make clear, are the complete box section of the bed, and the hollow box type of apron which is cast in one with the saddle. All gears in the apron run between two bearings. The lead screw is brought very close under the front flange of the bed, so that the drive of the saddle shall be as direct as possible, while the area and disposition of the wearing surfaces both combine to ensure the maintenance of the initial accuracy of the machine. The design of bed, saddle and loose headstock are well worth inspection. Another machine on the stand is a sensitive radial drilling machine, illustrated in Fig. 12. This is designed either for hand or foot power, especially for use in repair shops, garages, &c. The capacity of the machine is enormously in advance of anything previously accomplished with regard to foot-power drilling machines. The drill in question will comfortably put a 1-in. hole through cast-iron at the rate of 6 in. per minute without a smaller drill having previously been put through, and pin-drilling of considerably larger holes can be accomplished with equal ease. The working surface of the table top is 23 in. by 12 in., and a practically equal area is available on the back and front faces of the table. The arm will swing through 60 deg. on either side of its central position and the travel of the head along the arm is 18 in. The arm can be raised or lowered 6 in. on the column, and there is an additional sensitive motion of the drill spindle of 4½ in. The maximum overall height of the machine is 6 ft. 2 in., and the weight 720 lb. It can also be supplied with a direct connected electric motor drive if desired.

Another tool manufactured by Messrs. Drummond Brothers for the smaller machine shops, is a hand-shaping machine as illustrated in Fig. 13. It is generally similar to the larger pillar shaping machine of modern design, with the exception of course, that it is arranged to be operated by hand instead of by power. It is fitted with swivelling head with hand downward feed and hinged tool-box, the latter to take tools of ⅝ in. square steel. The table has both hand and self-acting traverse to right or left, and can be raised or lowered by a hand wheel. All operating screws are square threaded. The maximum stroke of the ram is 7 in., the table has a horizontal travel of the same length and a rise and fall of 4½ in. The tool can work at a maximum height of 4½ in. from the table, or 3 in. above the vice jaws. The machine is supplied complete with removable swivelling vice, as shown in the illustration, and the hole through the pillar permits the shaper to be used for cutting keyways or flats on shafts up to 1½ in. diameter and of any length.

(To be continued.)

NON-FERROUS METALS.—The following particulars are published of the stocks (exclusive of old metal and scrap) in this country of soft pig lead and refined spelter in the possession of the Minister of Munitions, on March 1, 1920: Soft pig lead, 40,435 tons; refined spelter, 7,299 tons. A proportion of these stocks is already sold to the trade for forward delivery.

THE DEVELOPMENT OF METAL CONSTRUCTION IN AIRCRAFT.*

By Major J. S. NICHOLSON, O.B.E., R.A.F.

(*Continued from page 362.*)

Comparison of the Experimentally Determined Characteristics of the Various Designs, with their Predetermined Characteristics.—Referring back to the pin-jointed strut with end thrust P, and lateral bending moment M, as shown in Fig. 1 (page 358 *ante*), the Perry formula gives:

$$f_c = \frac{P}{A} + M\left(\frac{Q}{Q-P}\right)\frac{y}{I} \quad . \quad . \quad (2a)$$

as the relation between f_c, the maximum stress developed, and the loading M and P for the case of uniformly-distributed lateral load. If the constants y, I and Q are known for the various test specimens, and if the numerical relationship of M to P is kept constant, the maximum stress f_c can be calculated for all values of P or M.

In Fig. 24 the graphs S_1, S_2, S_3 represent the relationship between the maximum compressive stress developed

Fig. 24. AVRO STEEL SPAR SPECIMENS. LOAD-STRESS CHARACTERISTIC CURVES.

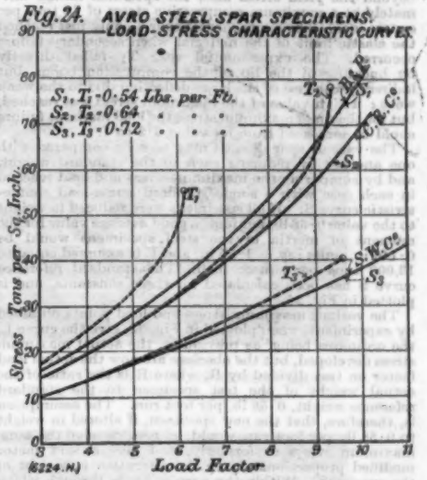
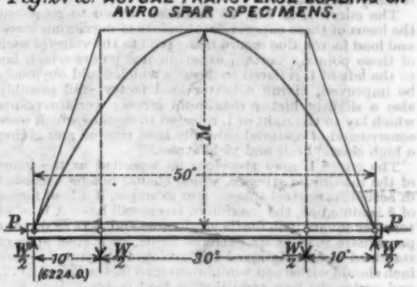


Fig. 24a. ACTUAL TRANSVERSE LOADING ON AVRO SPAR SPECIMENS.



and the load P or the load factor for three different steel spar specimens calculated on the assumption that E is 13,000 tons per square inch, and that the stress is everywhere within the elastic range.

S_1, S_2 and S_3, therefore, represent the ideal characteristics, and give the minimum stress which a definite loading will produce.

S_1 represents a Boulton and Paul specimen weighing 0·54 lb. per foot.

S_2 represents a cycle-rim specimen weighing 0·64 lb. per foot.

S_3 represents a Steel Wing Company's specimen weighing 0·72 lb. per foot.

The dotted curves T_1, T_2, T_3 show the actual load, stress characteristics obtained in each case respectively in tests to destruction of the three specimens.

In all three cases the actual experimental characteristic T lies above the calculated, ideal, characteristic S, showing that on test the stress developed for a given loading was greater than the stress as calculated by equation 2a (page 358 *ante*). This increased stress is caused (*a*) by any lack of alignment of the specimen; or (*b*) because the end load P does not pass through the centroid of the section of the specimen; or (*c*) because the shear deflection of the specimen is appreciable; or (*d*) because the material in the specimen is stressed beyond the elastic limit; or, broadly speaking, because the deflection of the specimen was greater than that assumed in the formula 2a, giving rise to an increased stress due to the end thrust bending moment P δ.

In the actual tests the transverse loading was applied, as is shown in Fig. 24a, where equal loads W are concentrated at 10 in. distance from the ends of the 50-in. specimen, giving a uniform bending moment M over

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* Paper read before the Institution of Engineers and Shipbuilders in Scotland, January 20, 1920.

the central 30 in. of the specimen, instead of the parabola for a uniformly distributed load.

If the maximum value M of the bending moment is the same in the two systems of loading, then the maximum deflection for the concentrated loading is $\frac{71}{600}\cdot\frac{M l^2}{EI}$, and for the uniformly-distributed loading it is $\frac{5}{48}\cdot\frac{M l^2}{EI}$ giving a deflection in the actual experiment of 13 per cent. greater than was assumed in equation 2A, or, making certain allowances such as for stiffness of loading boxes, &c., it may be assumed that, in the tests, the deflections due to the transverse loading were from 5 per cent. to 10 per cent. too great. This gives directly an increase from 5 per cent. to 10 per cent. in the end load bending-moment stress P δ, and will probably partly account for the curves T lying so far above S.

On the whole the experimental graphs T_2 and T_3 agree closely with their respectively calculated graphs S_2 and S_3 until, in the case of T_2, the material in the specimen is stressed beyond the elastic limit, and finally beyond the yield stress also, the specimen failing ultimately at a maximum compressive stress of 78 tons per square inch. The experimental spar T_3 only just reached the elastic limit of the material when secondary failure occurred. The experimental spar T_1 failed directly by buckling of the lip of the compression boom, but indirectly because of the large deflection due to the weak webs; a high value of the maximum stress was reached, but for the same maximum stress the load factor at failure could be increased from its value 6·2 to 7.

The various spar designs may now be compared with one another by reducing each to the standard weight, and by comparing the maximum stress and load reached in each case with a single standard stress-load characteristic curve S. If all specimens were reduced in weight to the value 0·58 lb. per foot, a good average value for the moment of inertia of the steel specimens would be 0·140 in. units; $y = 1·25$ in. and E is assumed equal to 13,000 tons per square inch. The standard reference curve S has been calculated for these constants, and is plotted in Fig. 25.

The various maximum stress and load points obtained by experiment, when plotted in Fig. 25, give the curve L, the ordinates being, as previously, the actual maximum stress developed, but the abscisse are now the actual load factor on test divided by R, where R is the ratio of the actual weight of the test specimen to the standard reference weight, 0·58 lb. per foot run. The assumption is, therefore, that the new specimen, if altered in weight to 0·58 lb. per foot run, would, on test, develop the same maximum stress as formerly, and give a load factor modified proportionately to the alteration in weight of the specimen. Within the narrow limits through which most of the test results were adjusted, this assumption is fairly accurate.

The curve L in Fig. 25 has been drawn to represent the locus of these experimental points of maximum stress and load factor, due regard being paid to the value of each of these points. Certain experimental points which lay to the left of L referred to designs which could obviously be improved, giving a better load factor, and possibly also a slightly higher maximum stress; certain points which lay to the right of L referred to designs which were constructed of material carefully heat-treated and giving a high elastic limit and yield stress.

The curve L may therefore be regarded as the locus of the maximum stresses, which should not be exceeded in actual Avro steel spars. For example, if a load factor of 8 is aimed at, the maximum stress will have A B = 44 tons per square inch for its ideal value and A D = 56 tons per square inch as its extreme value, or a steel spar of standard weight designed to develop 44 tons per square inch should withstand a minimum load factor E C of 6·75, and under the best conditions a load factor E B of 8.

Spars developing a low stress at failure, and having for compensation a relatively high moment of inertia, should coincide more nearly with, or perhaps even lie to the right of the standard curve S, and those developing the higher stresses will probably coincide more nearly with the experimental locus L. The higher the elastic limit and the yield stress of the material, and the more stable the design of a spar, the flatter will be its stress-load characteristic. A good example is the test curve T_2, obtained from a Dunlop spar specimen especially heat-treated after construction: the test characteristic of the same spar specimen before heat-treatment is shown at T_1 (see also page 360 *ante*).

The equation of the experimentally deduced locus curve L may be taken as the original equation 2A, with Young's modulus E, averaging 9,000 tons per square inch instead of 13,000 in the standard curve S.

With this information about the characteristics of the spar near to failure, and knowing fr m the design what the failing stress will be, it should be possible to predetermine, within narrow limits, the actual stress-load characteristic of the specimen. The curves S and L can be drawn for the test specimen with E = 13,000 tons per square inch and 9,000 tons per square inch respectively, and assuming that the maximum stress developed will be approximately 50 tons per square inch, the experimental stress load curve will lie close to S, and will terminate on the 50 tons per square inch stress line, somewhere near to the point where that stress line cuts the curve L.

Analysis of Duralumin Specimens for Avro Front Spar.—A similar analysis of the duralumin Avro spar specimens is shown in Fig. 26. T_1 and T_2 are the experimental curves for two specimens weighing respectively 0·41 lb. per foot and 0·52 lb. per foot. T_1 is the design of Professor Lea, and had its booms convex outwards; T_2 is illustrated in Fig. 7, on page 359 *ante*, and had its booms concave outwards.

S_1 and S_2 are the corresponding graphs calculated from equation 2A from the constants of the specimens, and assuming E to be 4,800 tons per square inch. S_3 is the calculated graph for a duralumin spar of standard weight and of design similar to S_2. The ends of the experimental curve T_1 and T_2 seem to lie on the curves L_1 and L_2, whose equations are those of S_1 and S_2, but with E equal to 3,000 tons per square inch and 2,800 tons per square inch respectively, instead of 4,800 tons per square inch.

Comparison of Duralumin Spar Specimens with Steel and with Timber Spar Specimens.—A comparison of Fig. 26 for duralumin with Fig. 25 for steel will show

Fig. 25. STRESS-LOAD CHARACTERISTICS FOR STEEL SPAR SPECIMENS WHEN REDUCED TO A COMMON WEIGHT PER FOOT RUN. — AVRO STEEL SPAR SPECIMENS.

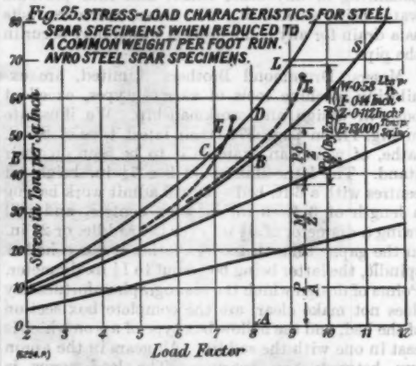


Fig. 26. STRESS-LOAD CHARACTERISTICS FOR AVR DURALUMIN FRONT SPAR SPECIMENS.

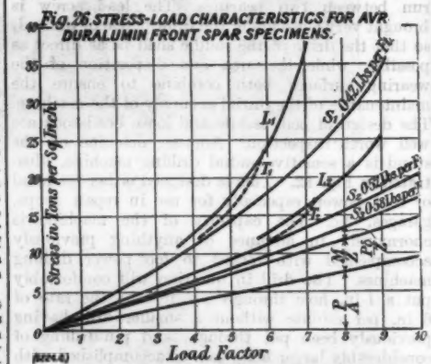
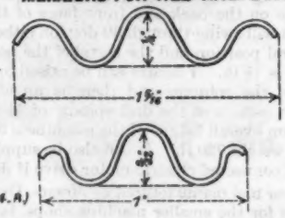


Fig. 28. SECTIONS OF CORRUGATED BRACING MEMBERS FOR WEB AND BOOM.



the radical difference between the various stress components $\frac{P}{A}$, $\frac{M}{Z}$ and $\frac{P\delta}{Z}$ in the two cases. The following data have been obtained from the graphs in these two figures:—

TABLE I.

Spar Specimen in each Case 0·58 Lb. per Ft.	Load Factor.	Developed Stress. Tons per Sq. In.				Percentage of Total Stress.		
		Total	$\frac{P}{A}$	$\frac{M}{Z}$	$\frac{P\delta}{Z}$	$\frac{P}{A}$	$\frac{M}{Z}$	$\frac{P\delta}{Z}$
Calculated graph S_2 (Fig. 26) ..	6	9·6	5·75	3·06	0·79	60·0	31·8	8·2
Duralumin spar ..	9	15·2	8·62	4·59	1·99	56·7	30·2	13·1
Calculated graph S (Fig. 25) ..	6	29·9	13·3	11·4	5·2	44·5	38·1	17·4
Steel spar ..	9	32·1	20·0	17·2	14·9	38·4	33·0	28·6
Experimental graph L_2 (Fig. 26)	6	10·5	5·75	3·06	1·69	54·7	29·2	16·1
Duralumin spar	9	18·0*	8·62	4·59	4·79	47·9	25·5	26·6
Experimental graph L (Fig. 25)	6	37·5	13·3	11·4	12·8	35·5	30·4	34·1
Steel spar ..	9	68·5	20·2	17·2	31·1	29·5	25·1	45·4

* The design of duralumin spar with concave booms would probably not develop more than 18 tons per square inch, and hence the maximum stress has been taken as 18 tons and not as 18·4 tons per square inch as in graph L_2, Fig. 26.

It will be seen that the stress due to end-load bending moment in the case of the duralumin Avro spar specimen is, even at high load factors, relatively only one-half as great as the corresponding stress in the steel spar, whilst the direct stress component $\frac{P}{A}$ is relatively greater in the case of the duralumin spar than in the steel spar. This difference is due to the relatively better value of Z, the modulus of section in the case of the duralumin spar. For the design shown in Fig. 7 with a concave boom and lattice web and with the standard weight of 0·58 lb. per foot run, the Z for duralumin is 0·382, against 0·112 for the steel spar. Other constants are as follows:—

TABLE II.

Ratio.	Density.		I.		E.		I.E. from Actual Test Specimens.
Duralumin	2·8	1	·382	3·43	4,800	1	3·43 = 1·26
Steel.	7·8	2·78	·112	1	13,000	2·71	2·71 = 1

The duralumin spar has, therefore, a 26 per cent. advantage over the steel spar, and hence the duralumin spar can only be equalled by a steel spar developing a very high stress. Table I gives for a load factor of 9, with standard spars, a stress of 18 tons per square inch in the duralumin against about 68 tons per square inch in the steel.

In the timber spar the load factor may be taken as 6, and to equal the strength of the timber spar, the duralumin spar must develop a stress of 10·5 tons per square inch, and the steel spar must develop a stress of 37·5 tons per square inch, both values well within the reach of very mediocre designs.

Comparison of Avro Spars with those of Typical Single-Bay and Two-Bay Machines up to 3,300 Lb.—Take for purposes of comparison the inner bay only of the machines. In the Avro the inner bay is 75 in. long; the front spar is 2½ in. deep, and the rear spar 2 in. deep. Hence $\frac{l}{d} = 30$ and 37·5 for the front and rear spars respectively. The spars are, therefore, very shallow, and hence the ratio $\frac{Q}{P}$ for these spars is 12·4 and 5·7 respectively for front and rear spars, see Table III, where Q is the Euler failing load for a free-ended strut and P is the end load. These values for $\frac{Q}{P}$ are exceptionally small, and are much smaller than is usual in either a two-bay or a single-bay machine.

TABLE III.

Ratio.	Front Spar.			Rear Spar.		
	Avro.	Two-bay Machine.	Single-bay Machine.	Avro.	Two-bay Machine.	Single-bay Machine.
$\frac{l}{d}$	30·0	22 to 15	27 to 18	37·5	24 to 18	30 to 21
$\frac{Q}{P}$	12·4	98 to 19·5	54 to 15·5	5·7	55 to 9	26 to 12

The ratio of the unit end load to the unit bending moment in the Avro machine is, on the average, slightly less than in other two-bay machines.

The Avro spars were, consequently, more difficult to design in metal, and especially in steel, than would have been the case for a machine with a smaller ratio of length of bay to depth of spar. For that reason certain of the spars supplied for the Avro could probably be employed without alteration for other and heavier machines, and, in other cases, the chief modification necessary would consist of a stiffening up of the webs of the spars to allow of their construction in sizes from 3 in. to 4½ in. deep.

It should, therefore, be possible to standardize certain of the more stable designs, keeping for example the section of the booms constant, and varying the depth of the webs to suit the varying aerofoil wing sections, and if an exceptionally strong spar of small depth were required it should be possible to mount two standard sections side by side and brace them together to form a single spar. Such a twin spar would have several advantages for the attachment of interplane struts, &c.

Larger-Sized Main Plane Spars Suitable for the Vimy and Handley-Page V 1,500 Machine.—In addition to the experiments carried out on the main planes for smaller and medium-sized machines, a considerable amount of work has been done on the development of metal construction for the largest types of aeroplanes.

These experimental spars may again be subdivided into (*a*) duralumin and (*b*) steel.

Following on their work with the small Avro spars, Messrs. Vickers, Limited, designed and constructed a large number of duralumin spar specimens for their Vimy aeroplane, and for the Handley-Page V 1,500 aeroplane.

Spar specimens of length equal to the distance between the points of contraflexure in the various bays of the main planes were tested in a similar manner to the Avro specimens, under combined transverse and end loading. Other specimens of length equal to the distance between consecutive compression ribs were tested as ball-ended struts.

The following data (Table IV) for the front spar in the upper wing of the Handley-Page V 1,500 machine

TABLE IV.

Position of Specimen.	Test Specimens.					Approximate Weight of Wooden Spar in Lb. per Foot Run.
	Combined Loading with Pin Ends.			Ball End Tests.		
	Length of Specimen between Roller Centres.	End Load in Lb.	Maximum Transverse B.M., in Ft.-Lb.	Length of Specimen between Ball Centres.	End Load in Lb.	
	ft. in.			ft. in.		
Outer bay	9 3	12,300	3,600	8 3	12,300	1·50
First intermediate ..	8 10	32,500	3,480	7 6	32,500	2·13
Second intermediate..	7 5	51,500	2,400	5 3	51,500	2·50
Inner bay	7 2	79,000	2,160	6 2	79,000	3·60

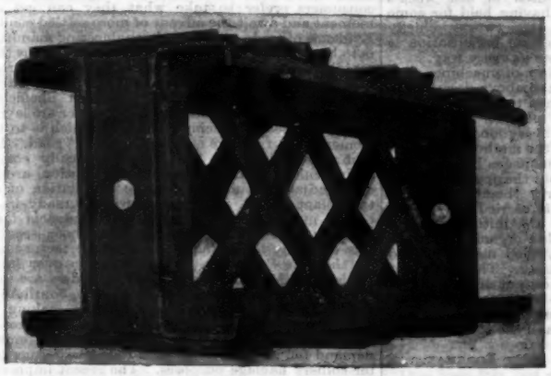


FIG. 27. DURALUMIN SPAR, SHOWING CHANNEL BRACING IN BOOM AND CORRUGATED BRACING ON WEBS.

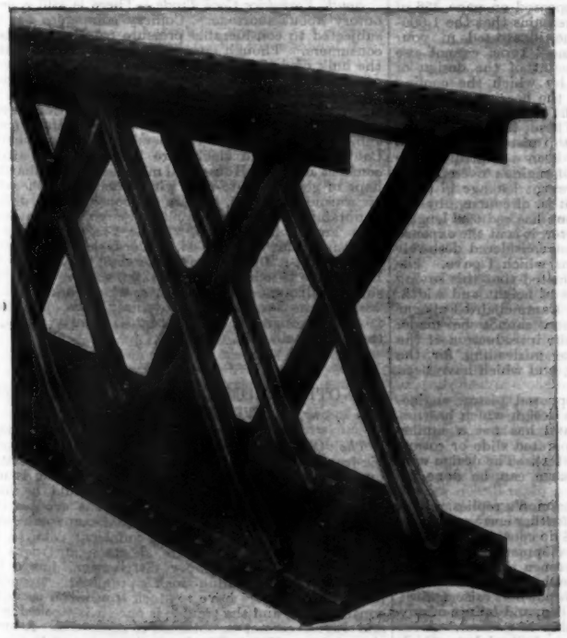


FIG. 29. DURALUMIN SPAR, SHOWING CONTINUOUS PLATE BRACING IN THE BOOMS.

FIG. 30. LATERAL LOWING OF COMPRESSION BOOM OF SPAR, TESTED UNDER COMBINED LOADING.

may be taken as typical of the requirements for these larger specimens. The loading given corresponds to four times the unit load for normal flight.

The overall dimensions of the wooden spar everywhere were approximately 4 in. wide by 8 in. deep. It was therefore, decided to keep the metal spars also of constant overall dimensions, approximately 4 in. by 8 in., and to experiment with spar specimens of a type similar to that already illustrated in Fig. 8 for the Avro duralumin spar (see page 359 *ante*).

By employing angles or channels for the main members of the spars it was possible to keep the length of side of these members constant, and by varying the thickness of metal, to get suitable strength, and also weights per foot run, for the loading in the different bays of the wings. Consecutive portions of the main-plane spars could also be butted together and connected simply to form a complete main-plane spar. The angle or channel design was also chosen on account of the ease with which the wing fittings could be attached.

With this type of design, on account of the size of the spar, and the specified weight per foot run, it was necessary to use thin sections of duralumin, and, in order to avoid secondary flexure of the angles the ratio of side of angle to thickness of metal had to be kept within 7 to 1. By keeping to this ratio of side to thickness in the outer bays where the loading is relatively small, and then by keeping the sides of the angle constant, the thickness of the angles in the inner bays would have exceeded 0·2 in.

This is the maximum size for drawn duralumin section and, consequently, for the heavier loaded bays a channel section was used for the main members of the spars instead of the plain angle section. This channel could have a width considerably greater than seven times its thickness without secondary failure occurring. These spar specimens with angle or channel main members had a lattice-web bracing composed of a double Warren system, each member in the bracing being riveted to the angle or channel members. The members of one Warren system were also riveted to those of the other system where they crossed at the neutral axis of the spar. A similar simple Warren system of short bracing members was employed with the booms.

Web and boom bracing members of simple channel section, 1¼ in. wide by ¼ in. deep, with flat sides, Fig. 27, and also of the corrugated type illustrated in Fig. 28, were employed in the earlier experiments.

An alternative modification for the boom bracing on the heavier spar sections consisted of a continuous

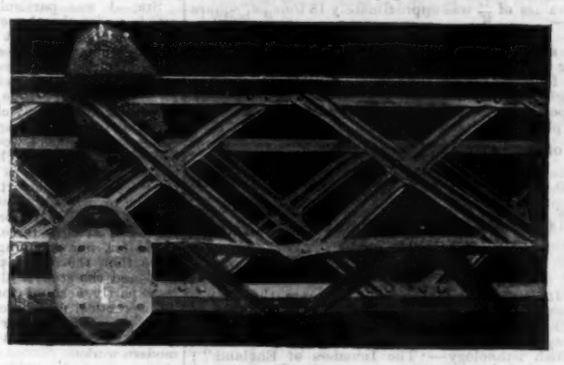


FIG. 30A. BUCKLING OF ONE ANGLE OF COMPRESSION BOOM AFTER THE WHOLE SPAR HAD BOWED LATERALLY.

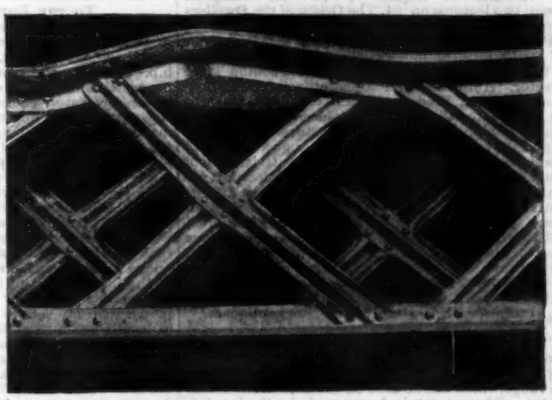


FIG. 31. BUCKLING OF DISHED PLATE AND ANGLES OF BOOM IN A COMPRESSION SPECIMEN.

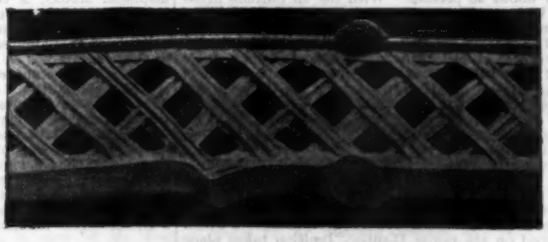


FIG. 32. BUCKLING OF COMPRESSION BOOM OF SPECIMEN UNDER COMBINED LOADING.

duralumin plate riveted to the angles and dished out in a similar manner to the Avro duralumin spar illustrated in Fig. 7. An example of this type of spar is shown in Fig. 29.

Typical failures of these spars are shown in the following: Figs. 30, 30A, 31 and 32.

Ball-End Strut Specimens.—These were tested in lengths equal to the distance between consecutive compression ribs. The spar specimens with lattice-boom bracings all failed initially by bowing sideways as a whole. In one case this was followed at once by the lateral collapse of one of the booms due to the weak bracing. This collapse of the boom bracing also occurred at a later stage in another case. In most of the other specimens the final failure occurred by the buckling of one of the angles on an unsupported length.

On plotting the maximum stress developed $\frac{P}{A}$, to a base of $\frac{L}{K}$, it was found that the limiting stress for small values of $\frac{L}{K}$ was approximately 18 tons per square inch.

The specimens with continuous dished-plate boom bracing mainly failed initially by bowing sideways as a whole, followed by buckling of a short length of plate and angle where unsupported by the web-lattice members. Two specimens, which failed initially by local buckling of the plate and angles of a boom, gave relatively high values of the maximum stress $\frac{P}{A}$.

From a consideration of the stress, $\frac{L}{K}$ graph, the limiting stress in this type of spar seemed also to be about 18 tons per square inch.

(*To be continued.*)

ROYAL INSTITUTION.—The following are the lecture arrangements at the Royal Institution after Easter: Major G. W. C. Kaye, two lectures on "Recent Advances in X-Ray Work"; Professor Arthur Keith, four lectures on British Ethnology—"The Invaders of England"; Major C. E. Inglis, two lectures on "The Evolution of large Bridge Construction"; Mr. Sidney Skinner, two lectures on "1. Ebullition and Evaporation," "2. The Tensile Strength of Liquids"; Mr. R. Campbell Thompson, two lectures on "1. The Origin of the Dwellers in Mesopotamia," "2. The Legends of the Babylonians"; Mr. A. P. Graves, two lectures on "Welsh and Irish Folk Songs" (with musical illustrations); Professor W. H. Eccles, two lectures on "The Thermionic Vacuum Tube as Detector, Amplifier and Generator of Electrical Oscillations"; Mr. Frederick Chamberlin, two lectures on the "Private Character of Queen Elizabeth"; Professor Frederic Harrison, two lectures on 1. "A Philosophical Synthesis as Proposed by Auguste Comte," 2. "The Reaction and the Critics of the Positivist School of Thought"; Professor J. H. Jeans, two lectures on "Recent Revolutions in Physical Science—1. The Theory of Relativity, 2. The Theory of Quanta" (the Tyndall Lectures.) The Friday evening meetings will be resumed on April 16, when Professor J. A. McClelland will deliver a discourse on "Ions and Nuclei." Succeeding discourses will probably be given by Professor H. Maxwell Lefroy, Professor F. O. Bower, the Right Hon. Lord Rayleigh, Professor Karl Pearson, Professor J. A. Fleming, Professor W. L. Bragg, and other gentlemen.

THE "WELCOMM" OIL HEATER.—We recently had an opportunity of witnessing a demonstration of the working of a new type of oil burner applied to a large cooking range, which will be used on the British Antarctic Expedition. The range, which was made by the London Warming and Ventilating Company, Limited, of 76, Newman-street, Oxford-street, London, W. 1, was designed for use with coal, and was large enough to cook food for about 60 persons. With the oil burners fitted by the Welcomm Heater (Parent) Company, Limited, of 11, York-street, St. James'-square, London, S.W. 1, the fuel cost is stated to be 3d. per hour with paraffin at 1s. 10d. per gallon. The burner is made from a single piece of steel tubing bent to form two U-shaped parts which are arranged horizontally, one a few inches above the other, with one arm of each U-tube connected by a vertical portion. Oil is fed, by gravity only, from an overhead tank fitted with a needle valve, through small-bore brass tubing into the free arm of the upper U-tube, which forms the vaporiser of the burner. In the large burner, above referred to, three small holes are drilled in each of the straight arms of the lower U-tube, in such a manner that, when working, the vapour escaping from the holes impinges on concave cast-iron deflectors which are slipped on the upper U-tube. Ignition takes place at, or near, the deflectors, which are, of course, maintained at a high temperature, and the oil, it is claimed, is thus completely consumed without causing carbonisation or noxious fumes. The demonstration was certainly satisfactory in every way. The burners are mounted on cast-iron trays measuring 5 in. by 4 in. in the smallest size, which gives two flames only instead of six. The tray is lined with asbestos on which methylated spirit is burned to start up the burner. Several different sizes are made for domestic ranges and coppers, industrial furnaces, hot-water systems, bakeries, laundries, &c., as well as for steam boilers. On account of its extreme simplicity, and the fact that the burner has merely to be placed in an existing coal grate without any fitting other than the running of an ¼-in. pipe between the tank and the burner, the apparatus appears to be well suited for domestic use. The convenience, economy, and saving of labour in comparison with coal, have also a special appeal in this particular application.

"AEROPLANE STRUCTURES."

TO THE EDITOR OF ENGINEERING.

SIR,—In the review of "Aeroplane Structures" published in your issue of March 5, it is stated that Morley's exact solution of the problem of the laterally-loaded strut is a less general case than Manderla's, since the end fixing moments are zero.

This is not quite accurate, and it may interest your reviewer to know that Morley in the paper referred to (*Phil. Mag.*, June, 1908) actually does obtain the solution assuming the ends are rigidly fixed. Exact solutions are also given for several other cases of loading.

I am, yours faithfully,

A. J. SUTTON PIPPARD.

Gwydir Chambers, 104, High Holborn, London, W.C. 1, March 12, 1920.

MANAGEMENT IN MODERATION.

TO THE EDITOR OF ENGINEERING.

SIR,—I was particularly interested in last week's article under the above heading, having held for some time the opinion that in many large works, chiefly engaged upon motor car manufacture, organisation is over organised, and retards progress in every way.

For some time I held a position of machine shop foreman in a very large works of the above description, my duties were chiefly clerical. I had to write orders for every shop drawing used by my men, for every limit gauge set, not once a week, but for every job on each and every shift. I had no choice as to the methods the work should be machined, as the shop manager himself said, the "Efficiency" department lay out the operations, and rightly or wrongly you must carry them out. Shop inspection and work progressing is carried out to the extent of being a farce. Results are, initiative is not asked for, nor encouraged, so-called organisation costs more than the actual production, good men get "fed up" and the staff is always changing. These systems may partly account for the low output of production. As a practical mechanic, I believe under present conditions, it is possible for production to be cheaper and quicker in old-fashioned shops than in the so-called large modern works.

SHOP FOREMAN.

"THE CAMMELLAIRD-FULLAGAR ENGINE."

TO THE EDITOR OF ENGINEERING.

SIR,—Despite Mr. Shannon's remarks re piston-cooling in general, in his letter which appeared on page 356 of your issue of March 12, the fact remains that the 1,000-h.p. Cammellaird-Fullagar engine illustrated in your paper, although an "open marine" type, cannot use water for p ston cooling on account of the design of the gear to the lower pistons, by which the cooling medium passes through a slot in the bearing surface of the crosshead slide, and further, the engine has telescopic pipes to the upper pistons. These telescopic pipes must be under pressure for the top pistons, and hence have packed glands, which have been a fruitful source of trouble in more than one type of engine; even having a flexible attachment will not prevent leakage in time.

As regards comparison of size, it is, of course, obvious that the Camellaird-Fullagar engine has reduced length, but as I pointed out in my first letter, it is at the expense of the introduction of features not considered desirable in a marine engine for the reasons which I gave. The sketch with my second letter indicated that this saving in length was also at the expense of height and width. No weights are given for the Cammellaird-Fullagar engine, so a complete comparison cannot be made. Comparison of length alone and the introduction of the words "equal rating" are quite misleading for the reasons given in a previous letter, and which have been evaded in Mr. Shannon's replies.

Regarding supercharging an opposed piston engine, it would be interesting to see the design which has not displaced cranks, is reversible, and has not a similar valve to the Sulzer "camshaft operated slide or rotary valve" (see Mr. Shannon's first letter). The design will, of course, be patented, so no harm can be done by publication.

In view of the nature of Mr. Shannon's replies, which are only generalities, I agree that further correspondence on those lines "is quite futile." I do consider, however, that at the present stage in the development of the Diesel engine, it is of the utmost importance that all designs should be most carefully considered before installation in a ship, as the chief point which shipowners raise against the Diesel engine is want of reliability, and failure of any engine reacts against the motor-ship in general. After all, criticism in the press is the least of all trials to which a Diesel engine for marine propulsion can be subjected.

Yours truly,

P. N. EVERETT.

29, Bede Burn-road, Jarrow-on-Tyne, March 15, 1920.

COALING AT SEA.—On February 29, the White Star Line steamer Belgic (Captain A. E. S. Hambleton) was the means of providing some badly-needed fuel to the American steamer Hilton, the ships then being some 300 miles from New York. The Hilton, bound for Boston, was displaying signals that she required assistance, and on the Belgic getting into communication with her it was ascertained that the American ship was short of coal, and asked for a supply to enable her to reach Boston. Captain Hambleton accordingly agreed to transfer the necessary quantity, which was conveyed in sacks, in the ships' boats, from the Belgic to the Hilton, a feat of no small difficulty owing to a heavy swell that existed at the time.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The general volume of business in steel, engineering and tools is on a much expanded basis. Firms have no difficulty in disposing of the whole of their current output. Full time working is the general rule in departments heavy and light. As a matter of fact, the amount of business booked represents only a small proportion of the tonnage sought by foreign buyers, but long-dated contracts are practically out of the question, with prices rising almost weekly. Producers can cover themselves in arranging for delivery several months ahead by quoting increased prices based on the abnormal advances of the past six months. This, of course, leads to the stipulation of figures, which, on the face of them, appear excessive, if not prohibitive. The only alternative is to insist on the insertion of a qualifying clause in contracts that prices ruling at the time of delivery shall be accepted as the basis of payment. A good many contracts for machinery and tools have been fixed up on the latter basis, but generally speaking consumers prefer to take what they can get at the moment and await the advent of more settled conditions. Evidence of trade expansion in engineering manufactures is to be found in the number of works extensions that are rapidly being pressed forward, despite the shortage of materials and labour. Several of these extensions locally are on a big scale. Between Sheffield and Rotherham, Messrs. Steel Peech and Tozer are laying the basis of a steel-producing extension, which is to have a tremendous frontage on the main road. Messrs. Cammell, Laird and Co. have practically completed their Penistone extensions, and, in addition, are laying down adjacent buildings for the installation of a new tyre plant. This, it is hoped, will be ready in about twelve months' time. Substantial contracts for steel railways, carriages and wagons have been secured by this company at the national ordnance factory erected by them at Penistone, and since taken over from the Ministry of Munitions. Substantial orders are in hand for steel, machinery, and tools for France, South America, Canada and Belgium. India is again making heavy purchases of railway springs, axles and tyres. An outstanding feature of the lighter trades is the tremendous demand for wire rope and wire rods, the former largely for colliery haulage purposes. The recent improvement in the crucible and high-speed steel trades is more than maintained. Pig-iron has advanced to 13*l.* a ton. Ordinary steel scrap is realising as much as 13 guineas, and steel turnings over 8*l.* a ton.

South Yorkshire Coal Trade.—There is still a general outcry about shortage. Colliery companies are being subjected to considerable pressure from merchants and consumers. Though current consumption accounts for the bulk of deliveries to the engineering trades, several of the largest firms in South Yorkshire are managing to pile up useful stocks against emergency. Exports from this area are practically nil, but collieries have no difficulty in disposing of the whole of their output, subject, of course, to the persistent wagon shortage. Cobbles, nuts and slacks are keenly sought after on contract account. House-coal merchants have abandoned hope of getting up-to-date with orders until the advent of warmer weather. There is considerable difficulty in obtaining maximum supplies of coke. Quotations:—Best branch handpicked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.*; Derbyshire best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; rough slacks, 24*s.* to 25*s.*; nutty slacks, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Supply of Cleveland pig-iron is inadequate to needs, so much so that the question of establishing a system of rationing is under consideration. An increased output would be indeed welcome, but there is no hope of the trouble being solved in that manner as already makers experience the greatest difficulty in obtaining sufficient coke to keep their furnaces going. Acute shortage of trucks continues to seriously hamper distribution, but a little better provision of rolling-stock is promised. Meanwhile, however, producers have to stock iron much needed for consumption, and the trouble is once it is stocked labour and wagons cannot be obtained to remove it. A further rise of 5*s.* in No. 2 Cleveland pig-iron, and in silicious iron, due, it is stated, to the extreme shortage of those commodities, has caused some surprise. For home consumption, No. 1 is now 212*s.* 6*d.* and silicious 217*s.* 6*d.* No. 3 and the inferior grades of Cleveland pig-iron remain at 200*s.* There are good Continental inquiries in the market, and for shipment to France, Belgium and Italy No. 1 is 217*s.* 6*d.* and No. 3 and the lower qualities are 205*s.* Cleveland iron is no longer quoted for despatch to other destinations abroad.

Hematite Iron.—The situation is very stringent in the East Coast hematite branch. Producers are well sold, and are not keen to make further forward contracts. No. 1 is 262*s.* 6*d.* and mixed Nos. are 260*s.*, and 10*s.* above these rates is named for export trade, but very little iron indeed is available for overseas trade.

Foreign Ore.—Definite quotations for foreign ore are difficult to fix. Buyers and sellers take a widely different view of what values should be. With consumers considering 50*s.*, on the 17*s.* Bilbao–Middlesbrough parity freight, quite a full figure for rubio of 50 per cent. quality,

with sellers naming a shilling or two above that figure, and with the latest freight fixture from the Spanish ore port 37*s.*, the c.i.f. Tees value of best rubio may be put at from 70*s.* upward.

Coke.—There is a most pronounced shortage of coke, and it is not surprising that values are moving upward. Local consumers are pressing for deliveries with very much less success than could be desired, and contracts running out cannot be renewed on anything like the terms on which they are expiring.

Manufactured Iron and Steel.—The finished iron and steel industries are characterised by great firmness, but conditions are such that little business is possible. Customers are undeterred by recent advances, and indeed, would pay above the high market quotations if they could be assured of delivery, but most manufacturers are so overwhelmed with work that they cannot entertain the business offering, and are compelled to turn down many substantial orders. They are chiefly occupied in endeavouring to fulfil obligations under contracts already made. The following are minimum market quotations: Common iron bars, 26*l.*; marked bars, 28*l.*; steel ship, bridge and tank plates, 22*l.*; steel boiler plates, 28*l.* 10*s.*; steel angles, 21*l.* 10*s.*; steel joists, 21*l.* 10*s.*; steel strip, 27*l.* 10*s.*; steel hoops, 27*l.* 10*s.*; soft steel billets, 21*l.*; hard steel billets, 22*l.*; packing steel (parallel), 18*l.* 5*s.*; packing steel (tapered), 22*l.* 10*s.*; heavy sections of steel rails, 21*l.*; and fish plates and sleepers, 26*l.*

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Markets.—A strike of colliery clerks employed by the Cambrian Combine in respect to grading, and a stoppage of work by the Combine colliers in sympathy with the clerks, caused the idleness of some 16,000 miners during the past week, with a consequent reduction in output. Yesterday, as the result of conferences, the Clerks' Union finally entered into an agreement with the South Wales Miners' Federation for a working arrangement between the two bodies. The basis of this agreement is that the clerks' organisation will become a constituent part of the Miners' Federation, with the Welsh organiser as agent to represent the interests of the clerks on the Miners' Federation. The ratification of this agreement was accompanied with a condition that the clerks at the Combine collieries should immediately resume work in order that the points at issue which led to the strike might be the subject of further negotiations. Work was, therefore, resumed on Wednesday. So far as the market is concerned, there is no material change, and export business continues very restricted by the difficulty shippers experience in obtaining releases and in securing coal from collieries, as practically the whole of outputs are already earmarked. The pressure for supplies to home ports has eased off slightly, but large quantities are now being shipped to coaling depots abroad, and it is only here and there that quantities are available for shipment to other foreign destinations. Exports last week totalled 350,197 tons, of which 224,956 tons went from Cardiff, 40,036 tons from Newport, 55,857 tons from Swansea and 29,348 tons from Port Talbot. The average f.o.b. prices of coal shipped abroad in February were higher than those obtained in January. Cardiff large averaged 85*s.* 4*d.* in February, compared with 75*s.* 9*d.* in January, Newport large 73*s.* 2*d.* against 68*s.* 5*d.*, Swansea large 76*s.* 10*d.* against 68*s.*, and Port Talbot large 85*s.* 3*d.* against 80*s.* 11*d.* These average prices, it should be explained, include contract values.

Colliery and Shipping Share Bonuses.—The United National Collieries, Limited, propose to increase its capital from 901,955*l.* to 1,828,020*l.*, and to issue as bonus shares 676,065 shares of 1*l.* each to ordinary shareholders in the proportion of one new share for every share held. The Penrikyber Navigation Colliery Company, Limited, is increasing its capital from 405,000*l.* to 550,000*l.* by the issue of 15,000 shares of 10*l.* each to ordinary shareholders, as a bonus at the rate of one for one. The Town Line (London), Limited, is increasing its capital from 250,000*l.* to 1,000,000*l.* by issue of 750,000 shares of 1*l.* each, 250,000 of which are to be given to existing shareholders as a bonus at the rate of one for one, 250,000 of which are to be offered to shareholders at 25*s.* each, and 250,000 of which are to be held for future issue.

The Iron and Steel Trade.—The strike of steel workers has ended and work resumed. At a meeting of the Conciliation Board yesterday proposals for future fluctuations of wages by means of a sliding scale were accepted by both sides. 5*l.* is to be the basis wages with 1½ per cent. for every 2*s.* 6*d.* advance or fall, with a monthly ascertainment. The employers decided to grant the claim of the men for a 40 per cent. increase in their base rates from January 1 last, the same as has been granted to the tin-plate workers.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The conditions prevailing in the Scotch steel trade are as brisk as ever, and even the latest advance in prices has failed to cause any check to the ever-pressing demand for material. With prices at their present abnormally high level one would almost have thought that there would have been a little holding back on the part of buyers, but the exact opposite is the case, and all seem more anxious than ever to get makers to accept their specifications. All classes of material are being sought, and there are many buyers for every ton of steel produced. The home trade still continues to receive the bulk of outputs, and there is very little available for shipment abroad. The plate mills are being kept going at top speed, and, despite the large tonnage being run through, the shipbuilding yards cannot get supplies adequate to their requirements. In order to provide for their needs several of the large shipbuilding firms have recently secured an interest in some of the steel manufacturing companies, and on account of these arrangements it is to be feared that the smaller firms may, in the near future, find it a little more difficult to secure a sufficiency of material for their operations. Sectional stuff is also in great demand and production is a long way behind requirements. In the steel sheet mills conditions are very active, and fresh business cannot be considered for months to come, and in consequence some very nice lots have had to be refused owing to previous bookings. Quite a fair demand exists for galvanised sheets, but if the price were a little more reasonable and more after buyers' ideas, quite a respectable business could be put through. In the meantime, however, only the most urgent orders are being placed, but makers say that owing to the extremely high costs of material and production, quotations cannot be steadied at the moment.

Malleable Iron Trade.—In the West of Scotland malleable iron trade a steady business is passing, and with order books so well filled for home consumption there is little or nothing left free for export. Prices have again been raised by 2*l.* per ton, and the current basis price for "crown" bars is now 26*l.* per ton, net, delivered at Glasgow station, while the export quotation is called from 27*l.* 5*s.* to 27*l.* 15*s.* per ton, net, f.o.b. Glasgow.

Scotch Pig-Iron Trade.—An extremely heavy demand exists for Scotch pig-iron, and the total output is being spread over as many customers as possible. While all grades are short this is particularly so in the case of No. 1 foundry iron, for which there is a very pressing demand at full prices. Fresh business in the market amounts to quite a large tonnage, but with nothing available for near date delivery much of it cannot be considered at all.

Shipbuilding.—Work in the shipbuilding yards is being pushed ahead with all speed, and much activity is general, but the difficulty of securing supplies of steel material has retarded progress in one or two cases. Some of the Clyde yards have felt the pinch recently, but nevertheless the output of new tonnage is on a large scale and the returns for this month are expected to be rather interesting. The booking of fresh contracts has been fair, but a certain amount of reticence prevails at present with regard to disclosing particulars of new orders. The industry all over is in a very healthy condition.

Locomotives.—An order of no little importance has just been secured by Messrs. William Beardmore and Co., Limited, and consists of 90 locomotives for the London and North-Western Railway Company. The building of locomotives is one of the most recent enterprises of Messrs. Beardmore, and the above large order will be constructed at their Dalmuir works.

MIDDLESBROUGH PIG-IRON SHIPMENTS.—In the latest statement issued by Messrs. William Jacks and Co., 5, East India-avenue, E.C., on the shipments of pig-iron from Middlesbrough and Skinningrove, the shipments for February were given as coastwise, 9,375 tons, and foreign 32,591 tons (including 500 tons to Germany), a total of 41,966 tons, as compared with 38,378 tons in January, 11,200 tons in February, 1919, and 26,491 tons in February, 1918.

PERSONAL.—The Zurich Polytechnic College has awarded the degree of Doctor of Science to Dr. Alfred J. Amsler, Schaffhouse, for his well-known work in regard to improvements of testing machines and scientific instruments. The firm of Alfred J. Amsler and Co. have recently appointed Mr. T. J. Primrose their British representative for dealing with both technical and commercial matters, at 162, Norwich-road, Ipswich.—Messrs. Armstrong and Main, Limited, state that on March 22 their London offices will be removed to Australia House, Strand, W.C.2.

THE MACHINE-TOOL TRADES ASSOCIATION.—In the annual report of the above association it is stated that the membership now stands at 145. Five firms have been refused admission. The association has made representations to the Ministry of Munitions in connection with the matter of the payment of overdue accounts, and has been able to effect a number of settlements. Some of the members had overdue accounts which had been outstanding for two or three years. Representations have been made to the Board of Trade with a view to the protection of the British machine-tool industry against German competition based on the low value of the mark. Members are requested not to purchase German machines. In connection with import restrictions it is pointed out that in view of Mr. Justice Sankey's decision affecting the importation of pyrogallic acid the Board of Trade has instructed the Customs to allow importation of gauges and other materials which were prohibited. It is reported that Mr. P. V. Vernon has been appointed to the Cutting Tools Research Committee of the Institution of Mechanical Engineers, and Mr. Charles Wicksteed has been appointed to the Advisory Council of the Loughborough Technical College. In connection with the Olympia Exhibition, to be held next September, it is reported that prospects are exceedingly satisfactory and that practically the whole of the available space is now booked. The annual dinner was held on the 10th inst. at the Connaught Rooms, when a number of very able speeches were delivered, notably by Sir H. J. Mackinder, Sir John Norton Griffiths and Mr. Robert Young. The association has taken new offices at 70, Victoria-street, S.W., and hopes to be in possession about the middle of April.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, March 19, at 6 p.m. Paper: "Exact Data on the Performance of Mechanical Stokers, as Applied to 'Lancashire' or other Narrow-Flued Boilers," by Mr. David Brownlie, of Manchester, Associate.

THE BRADFORD ENGINEERING SOCIETY.—Monday, March 22, at 7.45 p.m., in the Hall of the Bradford Technical College. Paper by Mr. D. H. Yates, M.Sc., on "The Uniflow Steam Engine."

THE INSTITUTE OF TRANSPORT.—Monday, March 22, Inaugural Meeting at the Institution of Civil Engineers, the Right Hon. Sir Eric Geddes, G.C.B., Minister of Transport, will deliver his presidential address.

THE ROYAL SOCIETY OF ARTS.—Wednesday afternoon, March 24. A paper on "Industrial Lighting in its Relation to Efficiency," will be read by Mr. Leon Gaster, Hon. Secretary of the Illuminating Engineering Society. The chair will be taken at 4.30 p.m. by Sir Henry Trueman Wood, M.A.

THE INSTITUTION OF NAVAL ARCHITECTS.—Wednesday, March 24, and two succeeding days, Meetings in the Hall of the Royal Society of Arts, John-street, Adelphi (by kind permission of the Council). Wednesday, March 24, at 11 a.m.: 6. Address by the President (the Right Hon. the Earl of Durham, K.G., G.C.V.O., P.C.); (1) "H.M.S. Hood," by Sir Eustace d'Eyncourt, K.C.B.; (2) "German Submarines," by Mr. A. W. Johns, R.C.N.C.; (3) "Experimental Work in Connection with Devices for Catching Submarines," by Mr. G. S. Baker, O.B.E. Thursday, March 25, at 11 a.m.: (4) "Notes on our Economic Position as a Shipbuilding Country," by Sir Alfred Yarrow, Bart.; (5) "Further Notes on the Dimensions of Cargo Vessels," by Mr. J. Anderson; (6) "Freeboard and Strength of Ships," by Mr. J. Bruhn, D.Sc. At 3 p.m.: (7) "The Stabilisation of Ships by Means of Gyroscopes," by Mr. P. R. Jackson; (8) "Yawing of Ships caused by Oscillation amongst Waves," by Professor K. Suyehiro, D.Eng. At 7.30 p.m.: (9) "Effect of Size upon Performance of Rigid Airships," by Mr. C. I. R. Campbell, R.C.N.C., and Mr. C. H. May, R.C.N.C.; (10) "The Effect of Holes, Cracks and other Discontinuities in Ship's Plating," by Professor E. G. Coker, D.Sc., F.R.S., and Mr. A. L. Kemball, Junr. Friday, March 26, at 11 a.m.: (11) "Experience and Practice in Mechanical Reduction Gears in Warships," by Engineer-Commander H. B. Tostevin, R.N., D.S.O.; (12) "Balancing of Rotors and the Determining of the Position and Amount of the Balancing Weights," by Mr. J. J. King-Salter, R.C.N.C.; (13) "Turbulent Fluid Motion and Skin Friction," by Professor T. H. Havelock, F.R.S.

THE ASSOCIATION OF DROP-FORGERS AND STAMPERS.—Wednesday, March 24, at 7.30 p.m., in Room No. 24, "Societies Room," Royal Technical College, George-street, Glasgow. Lecture by Mr. Harry Brearley on "Billets for Drop-Forgers."

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, March 25, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. Discussion on "The Electrical Equipment of Artisan Dwellings" (with introductory paper by Mr. L. Milne, Member), and "The Report of the Earthing Sub-Committee of the Wiring Rules Committee of the Institution."

THE CONCRETE INSTITUTE.—Thursday, March 25, at 7.30 p.m., Meeting in the Lecture Hall at Denison House, 296, Vauxhall Bridge-road, Westminster, S.W. 1. Paper by Mr. E. Lawrence Hall on "Steelwork in the New London County Hall" (lantern).

THE BIRMINGHAM METALLURGICAL SOCIETY.—Thursday, March 25, at 7 p.m., Meeting at the Birmingham Chamber of Commerce, New-street. Paper by Mr. T. Baker, D.Sc., M.Met., F.I.C. (Sheffield), "Some Thoughts on the Elastic Limit."

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, March 26, at 39, Victoria-street, S.W. 1, Lecturette, "The Future of the Gas Industry," by Mr. W. A. Tookey, M.I.Mech.E., Member.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, March 26, at 9 p.m., a discourse will be delivered by Professor Sir J. J. Thomson, O.M., LL.D., D.Sc., Pres.R.S., M.R.I. The subject is "The Scientific Work of the Late the Right Hon. Lord Rayleigh." Afternoon Lectures, at 3 p.m.: Tuesday, March 23, Professor Arthur Keith, M.D., LL.D., F.R.S., F.R.C.S., M.R.I., Fullerian Professor of Physiology, on "British Ethnology: The Invaders of England" (Lecture IV); Thursday, March 25, Mr. Stephen Graham, on "(2) The Hope for Russia"; Saturday, March 27, Professor Sir J. J. Thomson, O.M., LL.D., D.Sc., Pres.R.S., M.R.I., Professor of Natural Philosophy, on "Positive Rays" (Lecture VI).

THE WIRELESS SOCIETY OF LONDON.—Friday, March 26, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster. A paper will be read by Captain L. A. T. Broadwood, on "Harmonics in Continuous Wave Transmissions," illustrated by lantern slides and experiments. The business of the Meeting includes a discussion on the admission of lady members to the society.

THE ILLUMINATING ENGINEERING SOCIETY.—Tuesday, March 30, at 8 p.m., Meeting at the House of the Royal Society of Arts (John-street, Adelphi, London). Discussion on "Motor-Car Headlights in Relation to Traffic Requirements," opened by Mr. J. W. T. Walsh.

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EXHIBITS AT THE MOTOR-BOAT SHOW AT OLYMPIA.

(*For Description, see Page* 372.)

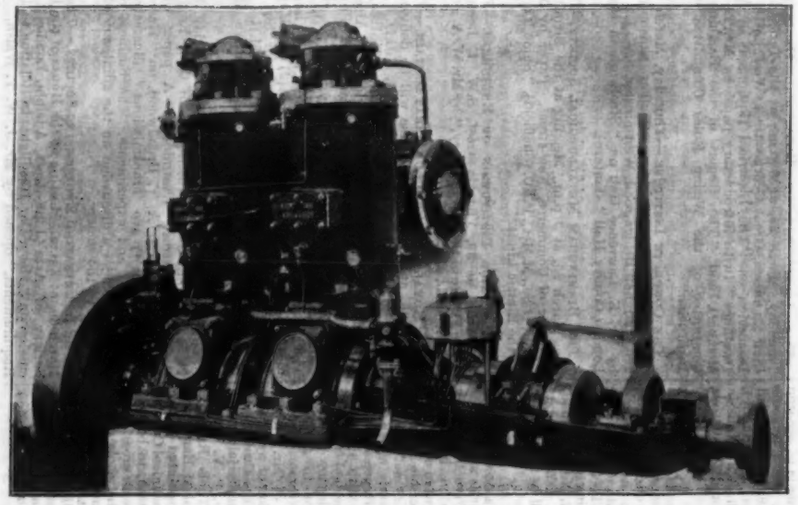


FIG. 1. 90 B.H.P. BRITISH KROMHOUT ENGINE; MESSRS. PERMAN AND CO., LTD., LONDON.

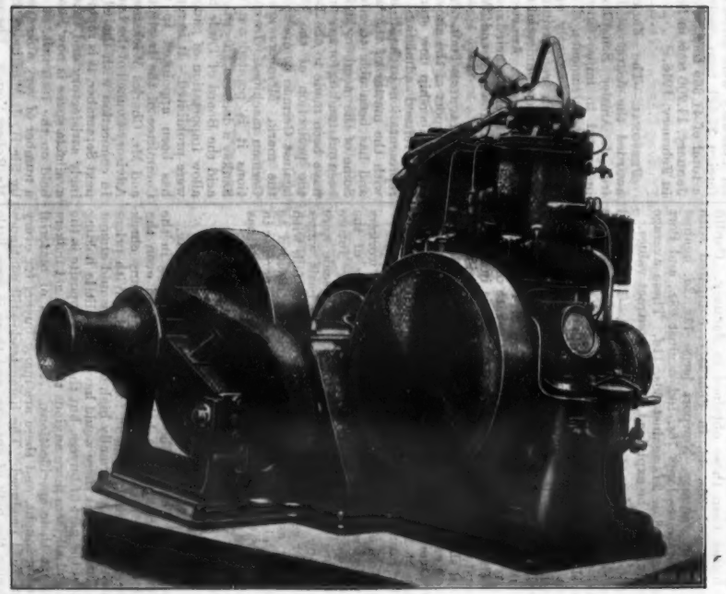


FIG. 2. CARGO WINCH; MESSRS. PERMAN AND CO., LTD., LONDON.

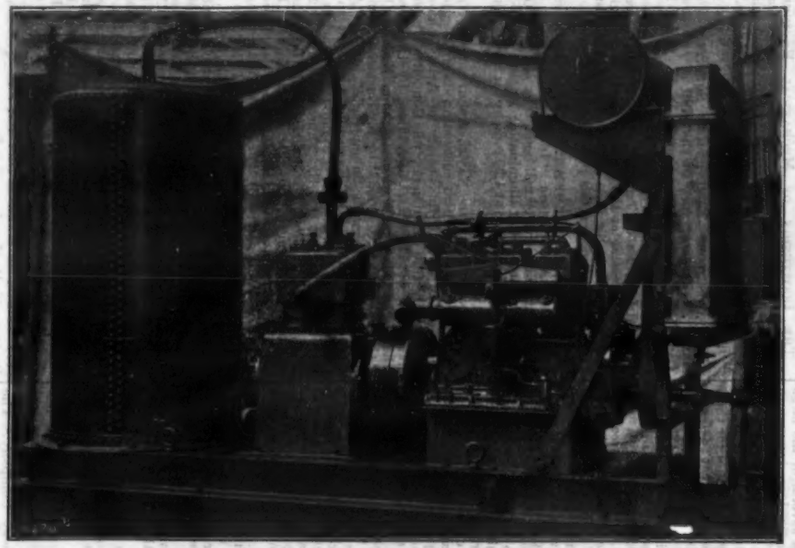


FIG. 3. 21-H.P. PARSONS' PARAFFIN ENGINE DRIVING A TWO-CYLINDER SINGLE-STAGE AIR COMPRESSOR; THE PARSONS' MOTOR COMPANY, LTD., SOUTHAMPTON.

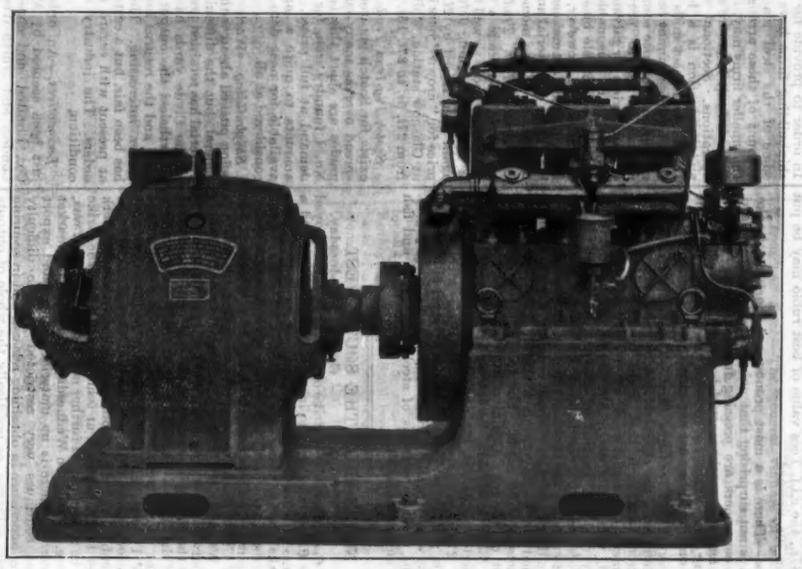


FIG. 4. THREE-CYLINDER PARSONS' PARAFFIN MOTOR DRIVING A 12-KW DYNAMO; THE PARSONS' MOTOR COMPANY, LTD., SOUTHAMPTON.

THE ARMSTRONG SHIPYARD AT HIGH WALKER-ON-TYNE; SI

(For Description, see P

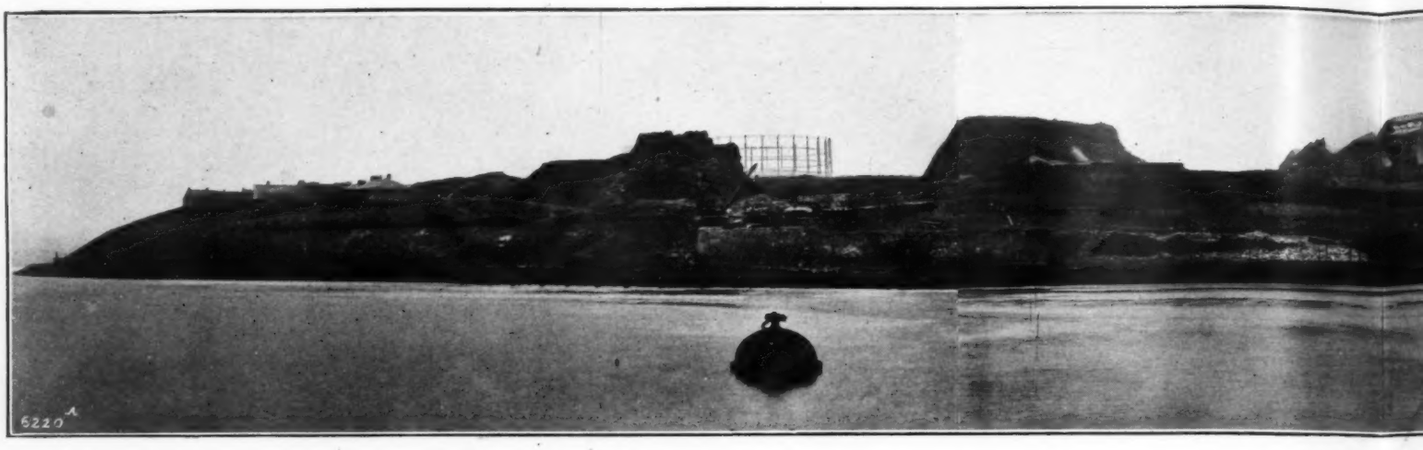


Fig 2. View of Site from River

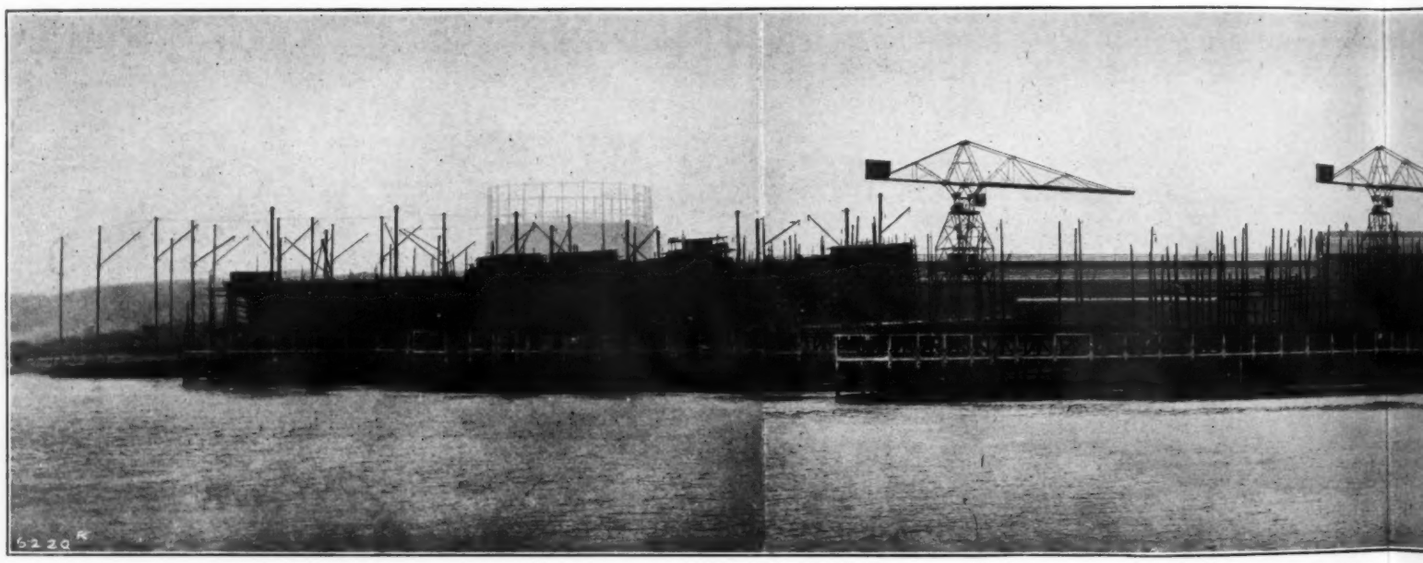


Fig. 3. View of Yard from Rive

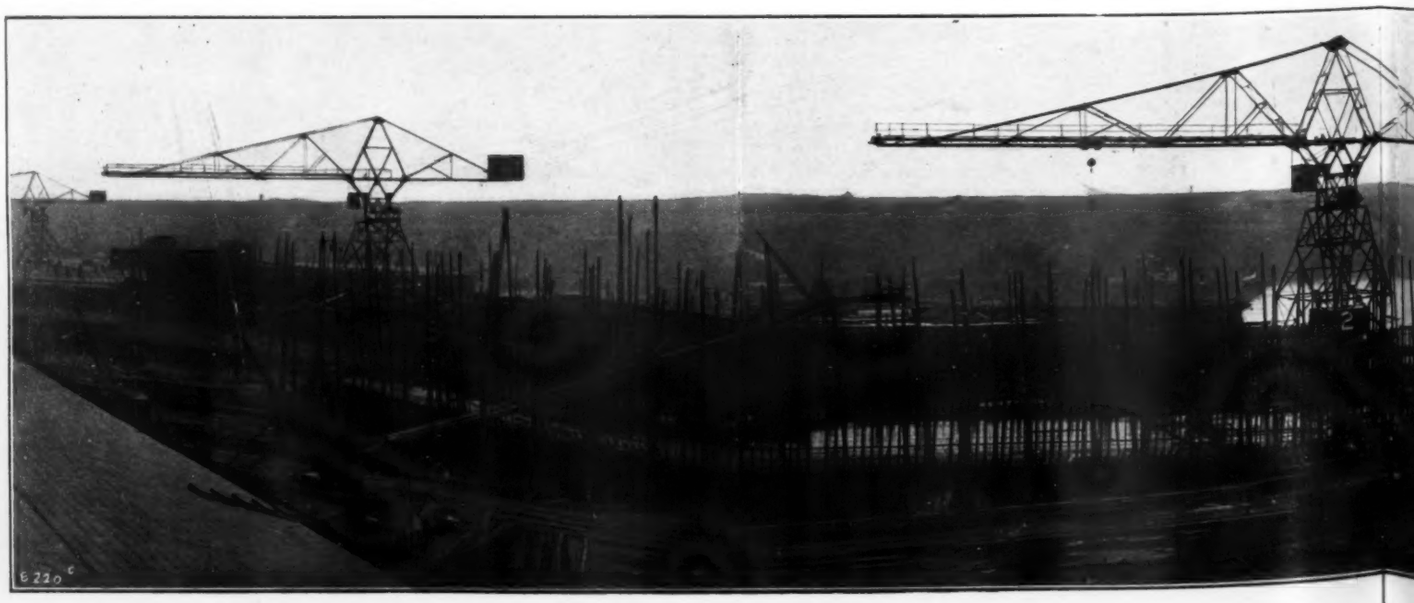
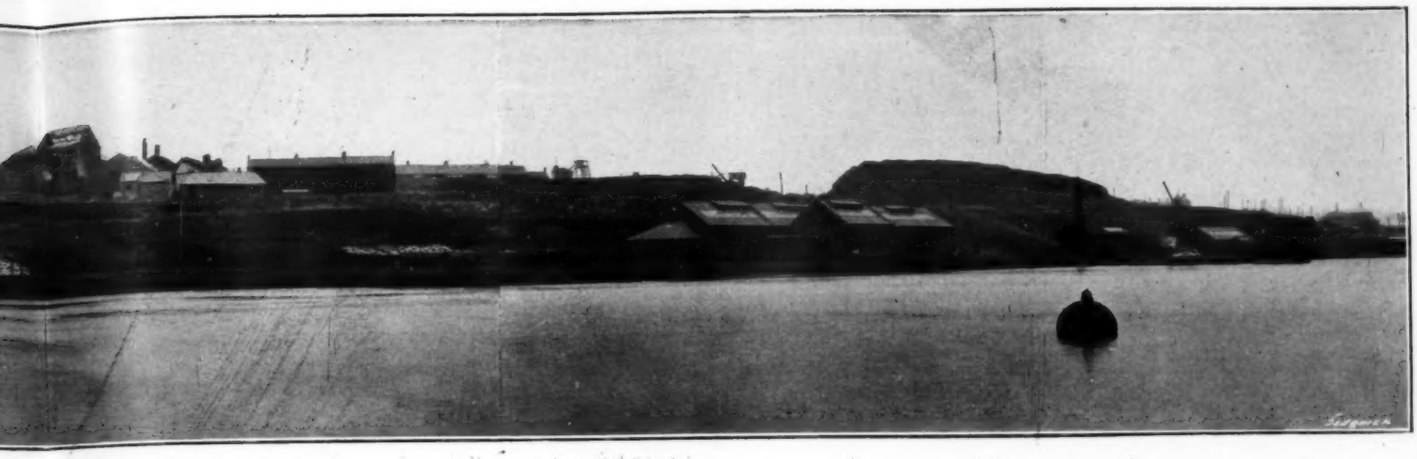


Fig 4. View of Large Building Berths from R

IE; SIR W. G. ARMSTRONG, WHITWORTH AND CO., LIMITED.

cription, see Page 366.)



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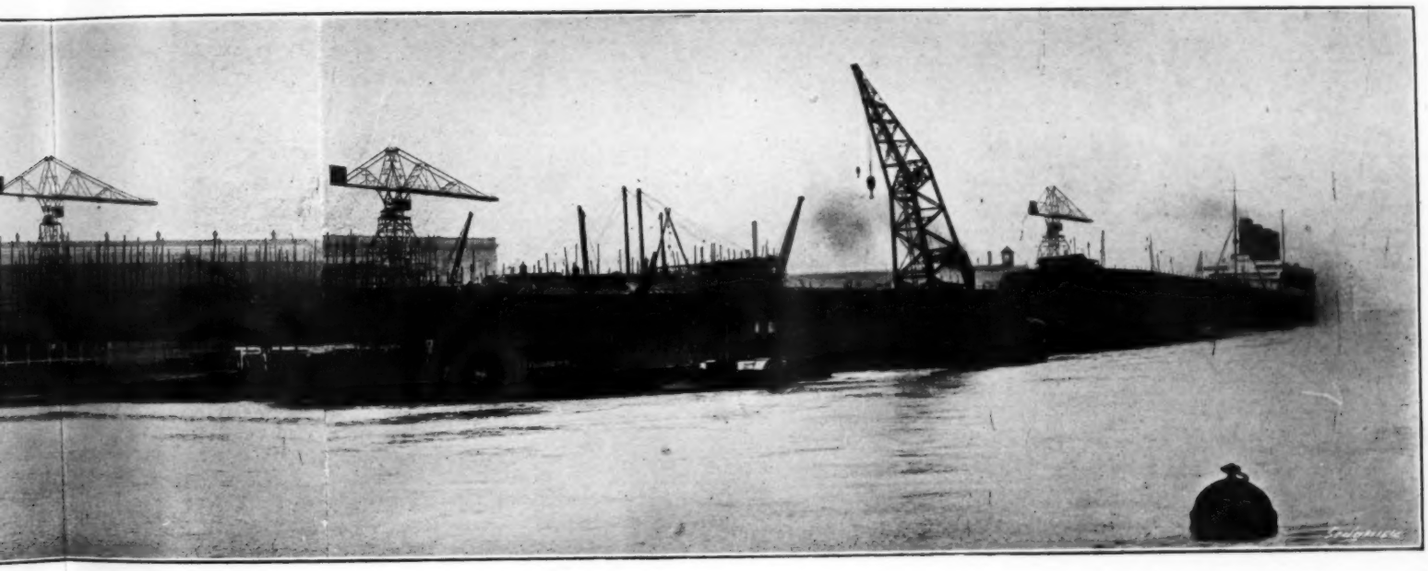

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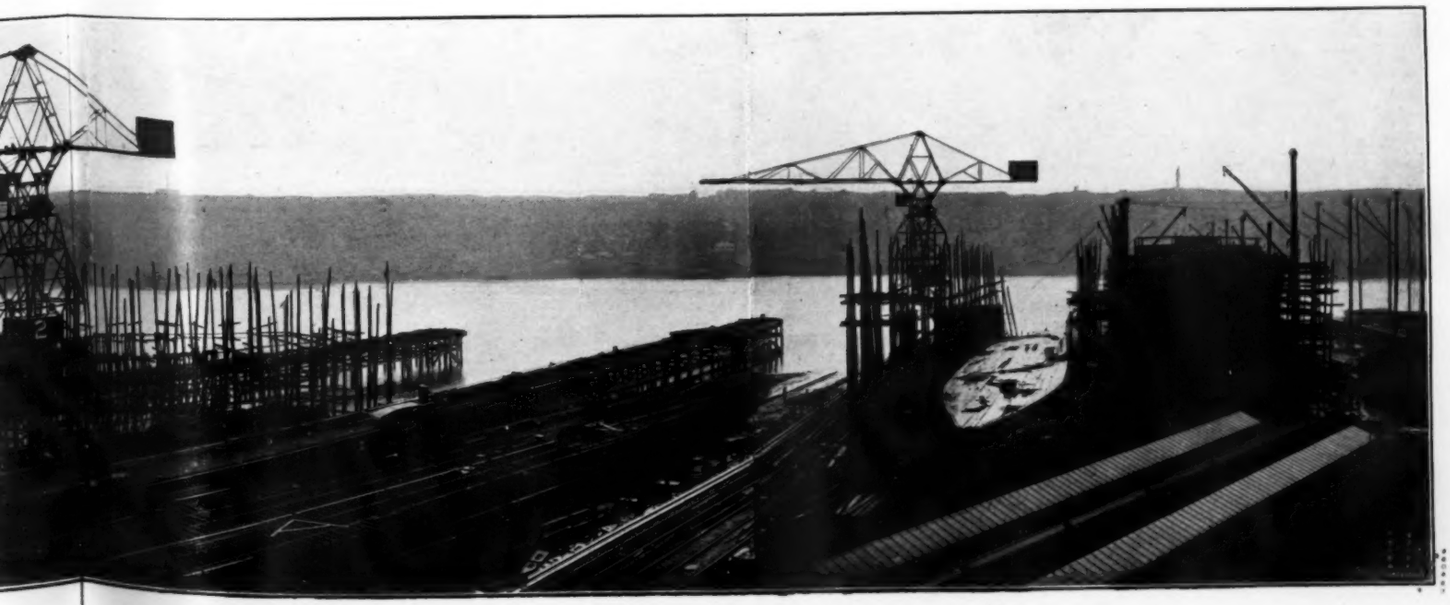

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"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

For the United Kingdom	£3 3 0
For Canada—	
Thin paper copies	£2 18 6
Thick „ „	£3 3 0
For all other places abroad—	
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When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

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Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C. 2.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON,
TELEPHONE NUMBERS—3668 and 3698 GERRARD.

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With a Two-Page Plate of the ARMSTRONG SHIPYARD AT HIGH WALKER-ON-TYNE; *SIR W. G. ARMSTRONG, WHITWORTH AND CO., LIMITED.*

NOTICE.

Owing to the enormous increases in the cost of paper, engravings, and printing charges generally, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 9d. to 1s. per copy. This increase dates from and includes the issue of Friday, January 2, 1920. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 379.

ENGINEERING.

FRIDAY, MARCH 19, 1920.

THE NAVY ESTIMATES.

ALTHOUGH the gross estimates of naval expenditure for the ensuing year issued this week and considered by the House of Commons on Wednesday, involve a sum nearly double that expended annually in pre-war days, there is little room for criticism on the grounds of extravagance in view of the conditions existing to-day. The gigantic efforts in naval construction made during the war period, and the victory over the direct menace to the world's peace, have enabled us to suspend production for the meantime, but it must be remembered that we still have certain definite duties to perform in support of Allied policy and to assist in restoring the disturbed conditions which exist in many parts of the world to something like normal order. It is also essential to maintain adequate facilities for sea-going training of our personnel, as well as to assist our trade and generally to support the needs of the Empire. This phase of the situation, and our naval policy generally, are admirably explained in the statement by Mr. Walter H. Long, the First Lord of the Admiralty, to whom personally is due, in large measure, that economy which has been achieved since the peace was signed.

In this discussion of naval policy there is raised the question of the future utility of the capital ship. The Admiralty still regards the capital ships as the main basis of sea power. That submersible vessels and aircraft, although undoubtedly extremely useful adjuncts to naval power, have by no means rendered existing capital ships obsolete has been amply demonstrated by the late war. The submarine campaign against our merchant ships could hardly have been inaugurated but for the existence, of the German High Sea Fleet. Enemy submarines however, did not interfere with the movements of our capital ships, and they were eventually defeated by destroyer screens, and new methods of attack. Aircraft must certainly be considered in connection with naval tactics of the future, but the view that it can only be regarded as an auxiliary to, and not as a substitute for, capital ships, for the present at all events, is, in our opinion, quite sound. At the same time it is likely that the design of battleships will be profoundly modified in the not far distant future, and it is the duty of the Naval Staff to keep fully abreast of all possible developments in this direction. A close study and analysis of strategy and tactics of the war, with the aid of manœuvres by our fleets, will greatly assist towards this end. It is a question where the attitude of hastening slowly, to use the Latin phrase, pre-eminently applies.

It is obviously of the utmost importance to ensure that the Navy should be kept fully cognisant of the latest developments in all branches of scientific research, so that these may be applied, where possible, to the needs of the Service without unnecessary delay. For this purpose a Department of Scientific Research and Experiment has been set up under the Controller of the Navy. A Director of Scientific Research has been appointed, who is responsible for the general direction and organisation of research work for naval purposes, as well as for keeping the Navy in touch with outside scientific establishments. He will also keep the Naval Staff aware of the possible practical applications of scientific progress in relation to naval needs. In addition to the ordinary naval establishments for gunnery, torpedo, mining, signalling and anti-submarine work the naval service needs a small central establishment for special research work and secret development. Such an establishment was formed during the war at Shandon, but, mainly on account of its isolated position, it has been decided to close this place and carry on all pure research work at a small Naval Institute in proximity to the National Physical Laboratory at Teddington; it is hoped that the new Naval Institute will be ready for work by the end of the present year.

Although the day is not in sight when air power may be regarded as a complete substitute for sea power, the aerial arm has already rendered such assistance in naval tactics and reconnaissance work that there can be little doubt that its employment will profoundly affect our future naval policy. For this reason it is essential to include in our naval organisation means which will enable the service to take full advantage of progress in aerial matters and to apply this progress to the art of naval warfare. A separate Naval Air Service is not contemplated, but arrangements have been made with the Air Ministry for close co-operation between the Admiralty Staff and the Air Staff, so that each is fully cognisant of the other's requirements. In order, however, clearly to define the functions of the two departments, the Admiralty have represented to the Air Council their opinion that the operations of all aircraft flown from His Majesty's ships, and that all operations of aircraft carried out in connection with the command at sea, should be under naval control. There appears to be no valid objection to this arrangement or to the proposal ultimately to form a naval wing under the Air Ministry with a personnel specially trained for naval work.

Turning now to the Navy Estimates for 1920-21, perhaps their most striking feature is the fact that, although no new construction is contemplated, the gross estimated cost of the Navy to the nation will be 96,590,181*l.*, the net estimated expenditure being 84,372,300*l.* and the appropriations in aid amounting to 12,217,881*l.* The net estimated expenditure is thus, as previously mentioned, almost double that for the last complete pre-war year 1913-14, for which year the corresponding figure was 48,732,621*l.* When, however, it is explained that over 19,000,000*l.* of the proposed expenditure is provided for non-recurrent war liabilities and terminal expenses, and that another 40,000,000*l.* is accounted for by recurrent expenditure due to war conditions, such as increases in prices and rates of wages, pensions, separation allowances, &c., it will be admitted that the remaining 37,500,000*l.*, which represents the normal expenditure on the basis of pre-war rates and prices, is by no means excessive. Nearly half the difference in the cost of the Navy for the years 1913-14, and 1920-21, is accounted for by the increased pay of officers and men, and the increased cost of victualling and clothing. These two items for the ensuing year amount to 21,459,000*l.* and 7,864,300*l.* (net estimate), respectively, whereas in 1913-14, the corresponding figures were 8,262,203*l.* and 3,034,246*l.*, although the personnel for the latter year was 142,960 as compared with 136,000 for 1920-21. A more instructive comparison of the items under these headings can, however, be made by considering the figures for the year 1912-13, for which year the personnel totalled 136,443, or practically the same as the estimated strength for the ensuing year. In 1912-13, the pay of officers and men amounted to 7,720,886*l.* so that the above-mentioned figure of 21,459,000*l.* for the ensuing year shows an increase of 178 per cent. The cost of clothing and victualling what is nearly the same number of men shows practically the same percentage increase, the figure for 1912-13 being 2,841,949*l.*, against 7,864,300*l.* for 1920-21, the increase in this item being in remarkably close agreement with the experience of most civilians. There are corresponding, and even greater, increases

in many other items such as medical establishments, martial law, educational and scientific services, pensions and miscellaneous items, but individually these items do not form large proportions of the total expenditure.

The publication of the present estimates in the familiar form of pre-war days throws an interesting light on the subject of naval expenditure during the course of the war. From the figures given it appears that the total annual naval expenditure rose from 103,301,862*l.* in the year 1914-15 to no less than 334,091,227*l.* in 1918-19. For the three intervening years the figures were 205,733,597*l.*, 209,877,218*l.*, and 227,388,891*l.*, respectively, while in the current year, 1919-20, the expenditure fell to 157,528,810*l.* The total expenditure since April, 1914, has thus reached the stupendous figure of 1,237,921,605*l.*, and, if we take the average annual expenditure under peace conditions as about 50,000,000*l.*, the naval cost of the war has been well over 900,000,000*l.* The personnel rose from a peace footing of 142,900 in 1913-14 to a maximum of 406,977 in 1917-18, while the expenditure on shipbuilding work, repairs and maintenance reached a maximum of 168,415,312*l.* in 1918-19, as compared with a little more than 24,000,000*l.* in 1913-14. In the record year the amounts expended on wages and materials in the Royal dockyards were 15,037,763*l.* and 59,128,675*l.*, respectively, while the remaining 94,248,874*l.* was paid for contract work; an additional expenditure of nearly 65,000,000*l.* was incurred during the same year for armaments.

For the ensuing year the estimated total expenditure on shipbuilding, repairs, maintenance, &c., is given as 28,641,700*l.*, most of which will be spent in the Royal dockyards. Before dealing with this item, however, it will be as well briefly to outline the general policy with regard to dockyard work. During the course of the war the Rosyth Dockyard was completed, so that there are now seven home dockyards instead of the six existing before the war; the others are, of course, at Portsmouth, Devonport, Chatham, Pembroke, Sheerness and Haulbowline.

At the outbreak of war about 42,000 men were employed on shipbuilding and repair work at these six yards, but at the time of the armistice, the number engaged amounted to 67,800, the increase being mostly in the engineering trades and in semi-skilled and unskilled labour, rather than in the number of shipwrights and allied trades. When the war work fell off, it was decided to effect the necessary reduction in numbers gradually by regular weekly discharges, so as to enable men to obtain employment in merchant yards, but the number absorbed in this way was relatively small owing to the fact that the men discharged belonged mostly to the engineering trades and to the semi-skilled and unskilled classes, whereas the requirements of the merchant yards were mainly for shipwrights. Subsequently considerable numbers of shipwrights were released from the dockyards to assist in the merchant yards, but the effect of this was to increase the existing disproportion between the trades employed in the dockyards. In these circumstances it was decided to reduce discharges during the winter as far as possible, and to push forward naval work that was intended to be deferred. In accordance with the recommendations of Lord Colwyn's Committee, the Admiralty are taking steps to lay down an oil tank steamer at Devonport and a second merchant ship at Pembroke. Other steps for undertaking similar work are being considered in order to reduce unemployment as far as possible, but, in spite of this, heavy discharges will have to be made in the coming year. The estimates allow for the employment of 40,213 established and hired artificers and labourers in the home dockyards in the ensuing year, and the wages bill for these men is estimated at 7,733,800*l.* This works out to an average weekly wage of 3*l.* 14*s.*, and it will perhaps be interesting to compare this figure with the corresponding figure for 1913-14. In the latter year the men employed totalled 37,325, and the wages amounted to 3,122,139*l.*, so that, in that year, the average weekly earnings per man would be about 32*s.* The present figure thus shows an increase of over 190 per cent. Of the total expenditure of 28,641,700*l.* for shipbuilding, repairs and maintenance, salaries and wages in the Government yards at home and abroad account for 10,184,000*l.*, materials for another 8,499,000*l.*, while 9,958,700*l.* will be spent with outside contractors. Only 3,992,500*l.* will be utilised for new construction, 2,809,500*l.* going to contractors and the remainder to the Government yards. A further sum of 6,260,000*l.* will be spent on armaments as compared with 4,747,829*l.* in 1913-14, and works, buildings and repairs at home and abroad account for another 5,209,000*l.* The most important items included under the latter heading are oil-fuel storage accommodation in various localities at home and abroad, and a variety of work at Rosyth, where 643,410*l.* will be spent. The remaining items are for medical establishments 677,300*l.*, martial law 504,500*l.*, educational services 430,300*l.*, scientific services 302,000*l.*, Royal Naval Reserves 479,800*l.*, miscellaneous 3,290,000*l.*, Admiralty office 1,554,000*l.*, half-pay 2,452,000*l.*, pensions 4,386,900*l.*, and civil superannuation 861,500*l.* These items, with those already enumerated, make up the total net estimate of 84,372,300*l.*, and considering the present value of money and the fact that the war was directly responsible for a large proportion of the proposed expenditure, we think that it will be generally admitted that the Government's policy of rigid economy has been faithfully followed by the Board of Admiralty in framing the estimates.

GEAR CUTTING.

PROBABLY nothing has done more to assist towards the present high state of development of gear-cutting, than the advance of the motor-car. It may, of course, be held conversely that nothing has so much helped the advance of the motor-car as the development of gearing, but the first is probably the truer way to look at the matter. Any considerable advance in a mechanical art, or a branch of a mechanical art, generally follows a demand, and without the call for silent and efficient gear which the motor-car raised, it is improbable that the manufacture of such gear would as yet have reached the stage it has. A later influence has crept in which has had effect on the development of gear-cutting in the application of gearing to marine and other turbine drives, and although the gearing thus called into being has been in many respects altogether outside the motor-car field, the new methods which turbine gearing has produced, have had and are likely to have, influence on motor-car gearing manufacture.

The earliest demand which the motor-car made on gearing probably was that it should not make a noise. Machine-cut gearing, one must pre-suppose, but even machine-cut gearing may be noisy, and the conditions in a motor-car are in many ways so much more onerous than in, say, a machine tool, that an entirely new order of accuracy of gearing came to be demanded. This necessarily led to a close examination of the theoretical adequacy of the methods of manufacture employed. The most obvious method of machining a spur-gear with straight teeth—the simplest form of gear—is to form the teeth with a rotary milling cutter. This method was developed to a very high degree and codified by Messrs. Brown and Sharpe. The method, however, has the defect that it is purely a copying process. If the milling cutter is not of the correct shape, the teeth formed will not be of the correct shape. The cutters are difficult and expensive to make and maintain with extreme accuracy, and have the further serious disadvantage that they are accurate only for one particular diameter of wheel being cut. In practice a series of cutters is generally used correct for certain diameters, but only approximately so for intermediate diameters.

The defects of the rotary cutter milling method of producing spur teeth are eliminated by the various methods of generation which have been devised, and as pointed out by Mr. P. J. Worsley in a paper read before the Institution of Automobile Engineers on the 10th inst., recent developments have been all in the direction of generation. Mr. Worsley reviewed the question of the cutting of gears of all such types as are normally used in motor-car construction, and in this matter of the generation of spur-gears described the action of the Bilgram, Reinecker, Fellows and Sunderland gear-cutting machines. The formation of a correct form of tooth in all these machines is based on the principle of a straight rack cutting tooth being rolled with the gear blank and at the same time given a reciprocating motion in the direction of the length of the tooth. This operation generates correct involute teeth on the blank, and has the great advantage that the cutting-tooth or tool is a straight-sided one, and, therefore, comparatively easy to make and maintain of the correct shape. In the Fellows gear-shaper the cutting-tool is actually in the form of a pinion, but the generation from a flat cutting tool is only stepped back one stage, since the cutting pinion is formed and sharpened by rolling it with a flat-sided emery-wheel. This takes the place of the straight tooth-cutter in the Bilgram machine.

The question of the accurate cutting of bevel gear is obviously a more difficult one than that of spur gear, since the curves of the faces of the teeth are continually changing from one end of the teeth to the other. As Mr. Worsley pointed out, one of the main problems which the motor car has put to the gear manufacturer has been in connection with the point where the main drive is turned through a right-angle at the junction of the propeller shaft with the rear axle. After the days of chains, this transmission was made by bevel gears, but a bevel wheel cut with a rotary milling cutter with a profile to suit the big end of the teeth does not give the accuracy and noiselessness which modern ideas demand for the service. A number of bevel gear planers have been designed, a not unusual arrangement, consisting of a tool, or tools, travelling on the surface of a cone and controlled by a former to give the tooth the shape required. The early Gleason and Sunderland machines belong to this class. They give involute, or modified involute teeth. These machines, working with a former, are of the copying type.

The origination of the most prominent form of bevel gear generating machine Mr. Worsley credits to Bilgram, who adopted as the basis of his system a crown or rack wheel and a straight-faced cutter representing the side of a straight tooth. The bevel blank to be cut is held on the axis of a cone which rolls as if on a crown wheel. A reciprocating motion of the tool towards the axis of the cone shapes a true curve on the tooth. The tooth produced is an octoid. Reinecker build a Bilgram machine fitted with automatic dividing, while David Brown and Sons also build a Bilgram model. The Gleason automatic bevel generator uses two tools one on each side of the tooth. The cutting is done by the flat sides of the tools representing the sides of one tooth in the crown wheel against which the gear rolls. The rolling action is controlled by a portion of a crown wheel and a toothed segment.

An attempt to still further reduce noise in motor cars was probably an important reason for the revival of the back axle worm drive, which recent years have seen. It requires no long memory, however, to recollect that the modern rear worm drive was not greeted with universal welcome. The drive has now reached a state of high efficiency, but has been and still is a matter on which there is considerable controversy. The hollow worm has been associated with the name of Lanchester and has been brought to a state of very high efficiency by the Lanchester Motor Company. Its production is a speciality of the firm. Messrs. David Brown and Sons have, on the other hand, developed the straight worm and have quite recently produced a new form of very high efficiency. In everyday practice worms are cut in a thread milling machine and the worm wheels are produced from hobs. For correct working the hob must be a duplicate of the worm as regards tooth form, but the section of the tooth is not the same normal to the run of the tooth or parallel to the axis of the worm. As a consequence the backing-off of the hob has to be normal to the helix. The thread milling cutter, however, will not exactly reproduce its shape on the worm due to interference with the sides of the groove it cuts. A balance has to be struck and it is usual to make the hob with straight-sided teeth in order to simplify

it and then correct the thread milling cutter for interference.

Spiral gears, so-called, have come to be used to a considerable extent in motor cars for driving auxiliaries. As Mr. Worsley pointed out "spiral" gears are really helical gears. A spiral is a curve in one plane. Mr. Worsley further pointed out that spiral gears are really worm gears with a difference in the ratio of the teeth, the number in the driving and driven wheels in spiral gears being usually about the same. Mr. Worsley went on to say that spiral gears usually had a helix at an angle of about 45 deg. to their axes, and the simplest way of cutting them was to use a horizontal milling machine with the table set over to the angle required. The blank was then driven by the dividing head through a train of gears to give the correct helix. An ordinary rotary gear cutter was used. Spiral gears cut in this way presented convex faces to each other, so that only point contact was made. A great improvement could be effected by giving the driven spiral a hollow face like a worm wheel. As spiral gears are only used as a rule for light drives at approximately equal speeds, the simple point contact construction should, however, frequently be all that is required.

The next point referred to by Mr. Worsley was that of helical tooth gearing. This, of course, has come much to the fore in connection with marine turbine transmissions. It has been adopted to but a very small extent in automobile work. Mr. Worsley stated that the well-known helical tooth gears of the Citroen Company were cut by an end-milling method. The machines were thus of the copying class. The curve produced on the tooth was not of standard shape, but one made to suit each particular case. The cutter head on the machine was traversed along a bed parallel to the axis of the blank, and the blank was at the same time slowly rotated. Machines for cutting helical tooth bevels were very similar, but the slide carrying the cutter was pivoted. Although no machine had appeared which would generate double helical bevel gear teeth of the theoretical shape a solution of the problem had been attempted by Mr. W. E. Sykes, of the Power Plant Company, who had designed and patented a machine, the development of which should make it possible to cut double helical gears of a quality to compare with the products of a Bilgram bevel gear shaper.

The final matter of gear cutting referred to by Mr. Worsley was that of spiral bevels. This form of gear has attracted much attention in the motor car world of late years, and the extent to which such bevels are now fitted is probably determined directly by the number of Gleason spiral bevel gear generators available. The wheels run very quietly and in this respect are equalled only by the worm drive. They are also easily produced. The machine is complicated in a sense, but the actual machining is straightforward. The teeth in a Gleason machine are generated on the same rolling principle as in the Bilgram machine. The cutting is performed by a series of tools mounted in a circular ring forming a large inserted tooth milling cutter, the diameter of which is such that a segment equivalent to the face width gives the desired angle of spiral. This is usually 25 deg. to 30 deg. in automobile gears. The cutter is carried in a milling head which rocks on a cradle in circular ways, and through this cradle the generating motion is applied to the cutter. The cutter and work roll together by means of a geared drive. The cut takes place during the up roll of the cutter and work and during the down roll the work is swung away from the cutter by the feed cam and is indexed and returned to the cutting position. One side of the teeth is first cut all round and then the cutter is adjusted for the other side.

MINERS' SAFETY LAMPS.

MINERS' lamps have undergone modifications and adaptations to various fuels in the century of their existence, but have changed little in principle. That was clear from the large collection of safety lamps which Professor Sir John Cadman, of Birmingham University, exhibited at the Royal Institution on March 8, when delivering his postponed lecture on "Miners' Lamps." If we disregard the electric lamp, to which Sir John did not refer in particular, all the lamps remain essentially wick flames surrounded by a gauze cylinder, the wire gauze preventing the flame from striking through the cylinder unless the gauze should become too hot. In mine air charged with methane, a bluish cap of burning methane is seen over the flame; that cap may attain a dangerous height, when the percentage of methane approaches the lower limit of methane-air explosibility (6·5 per cent.). Though such percentages are rare as averages, they have to be reckoned with, and Professor Cadman remarked that if the air issuing from British mines only carried 1½ per cent. of methane with it, that amount should suffice for lighting the whole country; so far no means had been devised for extracting the methane. Before the days of the safety lamp and—a very important feature—of mine ventilation, a man carrying a candle on the top of a pole was sent into the mine before the shift commenced in order to burn out the gas; the man lay flat down and escaped generally, but not always. In some districts a donkey was trained for this dangerous duty, and candles were fixed in its harness.

A series of terrible accidents occurring in the North of England in 1812 then drew Humphrey Davy's attention to the problem which, Sir John remarked, he studied so thoroughly on the spot and in the Royal Institution that little remained to be done. Systematic investigation of mine explosions, at any rate, was not taken up till within the last decades. But accidents continued after Davy's work, especially when ventilation improved, and miners were apt to open their lamps, which were only of ½ c.p. originally. The poor light was still the greatest drawback of the safety lamp. Davy happened to use a wire gauze with 784 apertures to the inch, and that mesh was subsequently adhered to and officially insisted upon, though Davy himself ascertained that 625 apertures would be safe. Thus safety was increased, and the light further reduced, by giving the lamp, in addition to its lantern or tin case, two and even three gauze shells in some Marsault types. On the other hand, the lower portion of the gauze cylinder was made of glass, and Muesseler gave the lamp a proper glass chimney to hasten the combustion.

The most recent improvements of miners' lamps due to W. Best, E. A. Hailwood and F. E. Patterson, aimed at better light, and their lamps actually yielded 2 candles, or even 3 candles; but even that was hardly sufficient, and the statistics from gassy mines and from safe mines, in which naked lights were permitted, left no doubt that the many modern cases of defective eyesight and concomitant disease must be ascribed to the low candle-power of the safety lamp. One may think that our ancestors might have been satisfied with such illumination; but their eyes were not spoiled by the glare of the electric lamps on other occasions. The inventors mentioned made use of tubes, annular passages, apertures and deflectors to let the preheated air directly impinge upon the flame or enter it from below, and they provided reflectors for the light, which the authorities did not favour. Others improved the lamps as a methane indicator; Clowes used a hydrogen flame as pilot jet, but that necessitated carrying a hydrogen cylinder; Sir Henry Cunynghame and Sir John Cadman himself supported an asbestos screen soaked with soda or copper chloride above the flame, the screen to be rendered bright incandescent by the cap and thus to give immediate distinct warning. The safety lamp was by no means perfect yet, Sir John remarked in conclusion, and we had to bear in mind in our attempts of improving it that the most dangerous explosions were now recognised to be due to coal dust, and not to methane.

NOTES.

THE ELECTRIC LAMP INDUSTRY.

THE report of a Sub-Committee of the Standing Committee on Trusts under the Profiteering Act, of 1919, was published on Wednesday. The findings briefly are that there is a trade combination in the electric lamp industry which has been created mainly in the interests of the British Thomson-Houston Company, the General Electric Company and Siemens Brothers; that this combination controls from 90 per cent. to 95 per cent. of the lamp industry in this country; and that it imposes conditions limiting output on its members. The sub-committee also finds that the trading discounts allowed to factors and retailers are too high, and that the standard vacuum lamp now sold to the public at 3s. could be sold at 2s. and still leave satisfactory profits. It is recommended that the operations of the combination should be subjected to public supervision. Anyone with any knowledge of electrical manufacture in this country will not require to be told that it has in the past been not altogether a gold mine. Anyone with a knowledge of the electric lamp industry will also not require to be told that it is mainly owing to the efforts of the Electric Lamp Manufacturers' Association and its predecessor, the Tungsten Lamp Association, that an important electric lamp manufacturing industry has been established in this country. Anyone having knowledge of present prices will be interested to know that the price to the public of the standard vacuum lamp has been increased about 26 per cent. since the beginning of the war. The main complaints about the Electric Lamp Manufacturers' Association appears to be that it allows too much profit to factors and retailers and that it imposes conditions affecting output on its members. As the association is a business concern, one may assume it does not give its sellers more profit than it considers necessary. The building up of an industry in this country in opposition to foreign competition is not an easy matter, and one imagines the profit of handling association goods is only such as the association considers necessary to get in and keep in. We have not sufficient knowledge of the domestic affairs of the association to know the reason for the limitation of output clause, but, as the sub-committee shows, the association has no effective monopolistic patent covering the ordinary vacuum tungsten lamp. It is not necessary for a firm to enter the association if it desires to remain outside, and the report gives the names of seven firms which have done so. It is stated that these outside firms sell to large consumers more cheaply than the association. If this is so, and if they sell an equally good article then they will ultimately get all the business. The association has no monopoly other than the monopoly that effective manufacture and good business methods gives them, and there is nothing to prevent an effective opposition starting operations to-morrow. If it is not worth anyone's while starting such an opposition, then the industry cannot be one offering, or yielding, exceptional profits.

SUBSCRIPTIONS TO TECHNICAL SOCIETIES.

At the dinner of the Institute of Metals, on Friday, the 12th inst., Dr. Blackwood Murray, president of the Institution of Engineers and Shipbuilders in Scotland, raised the subject of the increased subscriptions which the members of practically all technical and scientific institutions are now, or will soon be, called upon to pay. As the cost of everything, including paper and printing, has risen to such a degree, many of the Institutions have found it necessary to increase their subscriptions. This must necessarily bear hardly on a large number of the younger men, many of whom, with the increased cost of living without any commensurate increase of salary, find the additional burdens almost too great a strain for a slender purse. Before the war, to a young man starting on his career, the demand thus made was considerable. To fit himself for his profession it was necessary even then for him to join one or more of the Institutions. In many instances such membership is a *sine qua non* required by Government or other employers. The practice of demanding such a qualification is becoming commoner as time goes on, and the standard is now required, not as formerly in one institution only, but in one of many, according to the class of work. Dr. Blackwood Murray stated that he thought that either the Income-Tax Commissioners ought to give a rebate to young men on their subscriptions to societies which they are thus required to join, or the Government should give a subsidy to the societies to enable them to carry on without raising their subscriptions. One of the income-tax regulations allows for expenses necessary

to the practice of one's profession, but generally speaking it has not been the custom to interpret this as covering such contributions to technical societies. It may be pointed out that much of the useful research work of the world is done by the younger men of the profession, if not as principals, at least as responsible assistants. The societies often contribute funds to this work, and the whole profession subsequently benefits by the publication of the results. Thus the value of the expense is widely repaid. Under the changed conditions of these days even the research workers themselves will, among others, have to contribute towards the additional expense, which hardly seems like putting the saddle on the right horse. We do not expect much in the way of financial contribution from the State to the funds of technical societies, but we consider that some relief might be given, without jeopardising the stability of the calculations of the Chancellor of the Exchequer, to young professional men in the form of an income-tax rebate on these subscriptions. It would perhaps be necessary to introduce some limit of income beyond which the rebate would be disallowed, but we do not think there would be any great difficuty in finding a workable plan if the matter were seriously taken in hand.

THE CHEMICAL ENGINEER.

When it is remembered that this country has generally led the world in chemical investigation the anxiety which was felt in the early days of the war as to our supply of chemical products may, at first sight, seem rather surprising. The reason for it, however, was clearly shown by Lord Moulton in a recent lecture at the University College on the training and functions of the chemical engineer. What we lacked, the lecturer said, was not knowledge of chemistry so much as practical experience in the application of this knowledge on an industrial scale. The contrast between the research chemist and the chemical engineer was similar to that between the mathematician and the mechanical engineer. Research chemists and mathematicians had accomplished some marvellous work, but their work was done in what might be regarded as an ideal world. It was the duty of the mechanical engineer and the chemical engineer to produce the same results under conditions existing in the real world, and this work was far more difficult. The question of scale, Lord Moulton said, was of the utmost importance in chemical processes. In the laboratory small quantities of liquids could be poured by hand from one vessel to another in a few seconds, whereas, in industrial operations pumping would have to be resorted to, and the time taken might materially affect the results. To attain a uniform temperature throughout a large mass of material was also, the lecturer pointed out, a very difficult matter, and, in some cases a temperature variation of a few degrees would greatly reduce the yield of the particular substance being manufactured. In illustration of this point Lord Moulton reminded his audience that it was extremely difficult to roast a whole ox satisfactorily but a comparatively simple matter to cook an ordinary joint. Change of scale, in fact, introduced problems which needed nearly as much research for their solution as was required for the original discovery. To meet the wants of the real world the chemical engineer had also to consider questions of production, cheapness and efficiency, which questions, in fact, dominated the whole of his work. He must take the materials to hand, use them in the best possible way, and decide which form of plant for filtering, drying, heating, &c., would enable him to get the right results from the process in the most economical manner. In the past, Lord Moulton said, this country had largely neglected the problems of chemical engineering, but we had to consider them in the course of the war, and the great efforts made in that period should now be applied to the requirements of peace. For this purpose the mental equipment of the chemical engineer must include a very sound knowledge of general chemistry, and, more especially, he must thoroughly understand the physical properties of the substances he handled, so that he would know how various materials behaved under different conditions. In the course of his training it was essential that he should see chemical operations conducted on a scale large enough to introduce the difficulties above referred to, and this could only be done in a large laboratory devoted to this particular class of work. In this connection the lecturer said he was pleased to hear that an important development was being made at the University College in the immediate future, by the establishment of a Ramsay Memorial Laboratory of Chemical Engineering. As mentioned in our last issue, on page 342, a sum of 25,000*l.* has been voted by the Ramsay Memorial Fund towards the cost of this laboratory, but a further sum, estimated at 50,000*l.*, is still required for the completion of the building and its equipment. In view of the importance of the subject to the nation there should be no great difficulty in raising the sum still outstanding.

POSITIVE RAYS.

ON the afternoon of Saturday last, the 13th inst., at the Royal Institution, Professor Sir J. J. Thomson, O.M., President, Royal Society, delivered the fourth lecture of his course on the above-named subject.

He said that in devising the positive ray method of analysis he had had the expectation that it would provide means for determining the molecular weights of the gases present in the discharge tube, and he was also prepared to find that when the discharge passed there was a greater variety of substances present than had hitherto been suspected. This expectation was realised almost in the first set of experiments made. The slide reproduced in Fig. 1 showed the results obtained in one of these early experiments. In this case the discharge was passed through chloroform, and it would be seen what an extraordinary abundance of different atoms and molecules were employed in carrying the current and some of the molecules present were compounds not ordinarily met with. He did not expect, however, when he first took up this study, to be able to determine much more from his plates than the atomic or molecular weights of the carriers concerned, and he did not anticipate that it would be possible to find out much about their chemical properties. He did not, for instance, expect to be in a position to tell whether certain elements were electro-positive or electro-negative, or feel certain that he would be able to distinguish whether a line on his plates was due to the molecule of an element or to the molecule of a compound.

However, as nearly always happened in scientific investigations, much occurred that had not been foreseen in the experimenter's philosophy, and closer study of the traces on his plate showed that the lines recorded had peculiarities from which a great deal might be inferred with regard to the properties of the particles responsible for them. A glance at Fig. 1 sufficed to show how thoroughly a compound was split up by the discharge, and we might accordingly expect when the line, due to a molecule, was recognised on a plate, to find also a line due to an atom, but we had no reason to expect to find a line due to a double or multiple molecule. Again, if a line due to an atom were found on a plate we might expect to find also a line due to a molecule, which would be equivalent to a particle of twice the atomic weight, but there was no reason for anticipating that we should find on the plates lines due to particles of apparently one-half the atomic weight of the gas experimented with. Again, with a discharge tube containing CO, and nothing else, we should not expect to find a line due to a particle weighing, apparently, one-half as much as the molecule of CO, though we would expect to find lines corresponding to oxygen and carbon atoms, with weights of 16 and 12 respectively. The absence or presence of a line corresponding to the half value of a molecule might thus afford evidence as to whether a molecule was that of an element or of a compound.

It was found, as matters turned out, that lines due to atoms were often accompanied by lines due to particles of apparently half the atomic weight. Thus in Fig. 2 the triplet of lines marked *a*, *b* and *c* were due, respectively, to carbon, nitrogen, and oxygen atoms, having weights of 12, 14 and 16 respectively. Above these was found another triplet of faint lines, due to particles with apparently atomic weights of 6, 7 and 8 respectively. At first it was thought that these lines might be due to three new

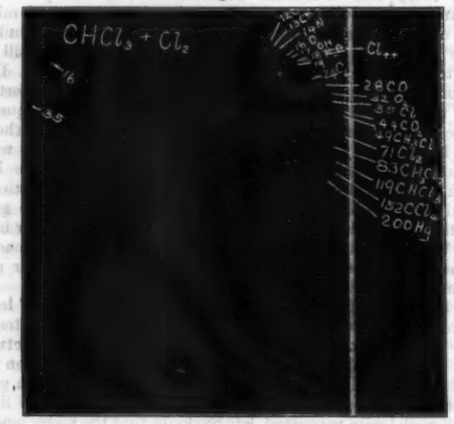


FIG. 1.

FIG. 2.

elements, but further study showed that they actually were produced by atoms of carbon, nitrogen and oxygen each carrying two charges instead of one.

Again, it might seem impracticable to distinguish a line due to a molecule from one due to an atom, but it was found that certain lines had protuberances, the tips of which were only half as far as usual from a vertical through the centre point. This implied that the particles to which these beaks were due had twice the amount of kinetic energy of those responsible for the normal parabolas. This was particularly well shown in Fig. 3 (reproduced from our issue of last week). Here the discharge tube contained very pure oxygen, and the two principal lines visible were due to the oxygen atoms and the oxygen molecule respectively. The line due to the atom was prolonged by a beak reaching, as already explained, half way to the vertical through the centre spot. Above this line came a faint line at B, corresponding to an apparent atomic weight of 8, which was due to an atom of oxygen carrying two charges instead of one. He would, Professor Thomson proceeded, say a further word on how these beaks were produced, as the matter had now become one of the very highest importance because to a large extent, these beaks served to distinguish whether a line were due to the atom of an element or to the molecule of a compound. Thus Mr. Aston had determined by his "focus method" (described in the last lecture), the

atomic weight of chlorine, which came out at exactly 35·0 (taking oxygen as 16). There was not a trace on his plates of any atom with an atomic weight of 35·5, but he always found associated with this chlorine line at 35, lines corresponding to atomic weights of 37, 39, and so on. These lines might be due to hydrides of chlorine such as ClH_2, ClH_4, ClH_6, or might be due, as Mr. Aston maintained, to isotopes of chlorine, that was to say to elements having the same chemical properties as the main chlorine constituent, and hence extraordinarily difficult to separate from it by chemical methods. The point was of the greatest importance, since the atomic weight of chlorine, as determined by chemists at 35·5 had been considered accurate within an error of less than $\frac{1}{10}$ of one per cent. The huge discrepancy between this value and the value of 35, Mr. Aston accounted for by maintaining that the chemist had always worked with a mixture of two substances which he was unable to separate by the methods at his command. On this view there were two different chlorines

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

with atomic weights of 35 and 37 respectively and possibly, also another chlorine with an atomic weight of 39.

The question at once arose as to what evidence there was for believing the line corresponding to an atomic weight of 37 was really due to an isotope which was an element and not really a hydride which was a compound. The answer to this question was derived from the study of photographs of positive rays. As a matter of experience it was found (with at most, one or two exceptions) that the protruding beak above described, was never present on other than a line due to an atom of an element. It was not found on lines due to molecules, whether molecules of elements or molecules of compounds. When present these beaks were always accompanied by lines corresponding to particles with an apparent atomic weight equal to one-half that of the particle responsible for the protruding beak. The point at issue here was one of quite fundamental importance, since Mr. Aston's measurements revolutionised the whole series of atomic weights.

Taking oxygen at 16, then in agreement with the chemists, Mr. Aston found hydrogen to have an atomic weight of 1·008, but the atomic weights of all other elements turned out to be whole numbers in accord with Prout's hypothesis. This was a most revolutionary result, and there was a natural desire to know the evidence which was held to establish it.

One criterion relied upon was the existence of doubly charged atoms. The beaks shown on certain atomic lines implied that the particles producing them had more than the normal kinetic energy. They were thus not so easily deflected by the electric field through which they were caused to pass. Each particle got its energy in the discharge tube, and if certain of them carried double charges the amount of energy acquired there would be doubled. If this additional charge were retained after passing through the cathode and in passing through the electric and magnetic fields employed to sort the particles out, as explained in a previous lecture, the result would be that the deflections produced by these fields would also be doubled, and the parabola traced on the plate would terminate in the normal position. If, however, the particle lost one of its charges after passing into the tube through the cathode but before passing through the electric field used to deflect it, it would in view of its greater kinetic energy, be pushed back less than the normal distance, and we thus got the beak. It would be seen that two processes were involved in the formation of these beaks. In the first place the particle must have acquired a double charge in the discharge tube, and secondly, it must in some way get rid of this additional charge after entering the channel through the cathode. Over 2,000 plates were now stored at the Cavendish laboratory, and as an empirical rule derived from the examination of thousands of plates it might said that the capacity of acquiring a double charge was possessed by the atom alone and not by the molecule. Only one exception to this rule was known, and this was of extremely rare occurrence. In some half-dozen plates out of the thousands the lecturer had examined it was found that in the case of a line corresponding to an apparent atomic weight of 28, and due accordingly either to a molecule of N or to one of CO, the parabola was prolonged by a beak, showing that this particular particle was capable of acquiring a double charge. This, however, was the sole instance known, and hence, as a working rule, satisfied in an enormous majority of cases, it might be said that atoms only had the property of acquiring double charges.

In Mr. Aston's experiments on chlorine he found associated with the lines corresponding to atomic weights of 35, 37 and 39, lines corresponding to apparent atomic weights of 17·5, 18·5, and perhaps, 19·5. Hence he concluded that the particles which produced the lines 35 and 37 were capable of acquiring double charges, and were thus atomic, that with an atomic weight of 37 being an isotope of chlorine. On the other hand some of the lines he observed close to the chlorine line were not accompanied by lines corresponding to $\frac{1}{2}$ values of their apparent atomic weights. He concluded accordingly that these lines were due to hydrides of chlorine.

He did not wish, Sir Joseph continued, to put the evidence higher than it actually was. Mr. Aston's conclusion as to the isotope was founded on an empirical rule, and it might turn out that the isotope was farther away from the principal constituent of ordinary chlorine than Mr. Aston thought. Some years ago the speaker had himself tried to find a chlorine isotope. His apparatus certainly did not give nearly so large a dispersion as that devised by Mr. Aston, but he had found no signs of an isotope near the chlorine line. There was, however, no getting away from Mr. Aston's main result, viz., that the atomic weight of chlorine was 35 and not 35·5, but how this was to be explained was, of course, another matter.

Further evidence as to the nature of the particles carrying double charges had been obtained by Stark. He found that the spectrum given by an atom carrying two charges was not the same as the spectrum observed with particles carrying one charge only. The method employed by Stark was a very interesting one. It was based on Döppler's principle, according to which a star rapidly approaching us looked bluer than it would if at rest relatively to the earth. All the lines in the spectrum given by a star moving towards us were shifted towards the blue end of the spectrum. The positive ray particles moved with a speed which might, in a normal tube, be as much as $\frac{1}{10}$ that of light. Such a relative speed would be enormous in the case of a star, and hence when the light from the positive rays was examined in a spectroscope the Döppler effect was very marked. If, for instance, doubly and singly charged atoms of oxygen existed in the same tube we had in effect two different kinds of oxygen present. Since the doubly charged atoms acquired higher speeds than the singly charged ones, the shifting of the lines would be greater for these. On examining such spectra Stark found that the displacement was not the same for all the lines in the spectrum. Those lines for which the shift was greatest must accordingly be due to doubly charged atoms, and those showing a smaller displacement to more slowly moving atoms carrying a single charge. The lines in a spectrum had been classified into series by Rydberg, and Stark found that the "sharp" series was due to atoms carrying double charges, and the diffuse series to lines having but a single charge. In the case of mercury, which could carry as many as seven charges, Stark found that to each charge carried, corresponded a different type of spectrum, so that these differently charged atoms had different properties.

Another peculiarity was at times observed in positive ray photographs. Thus referring to Fig. 4 we had two lines with the peculiarity, that the first part of the second line was exceedingly faint, the line only becoming bright at double the normal distance from the vertical through the centre point. Incidentally, it should be noted that the head of the upper parabola and the head of the bright portion of the lower curve lay on the same horizontal line. Again, in Fig. 5 the innermost line was produced by the mercury atom. At first this line was strong, then it faded away to become brighter further on. This was followed by another region of faintness, followed by another bright spot, and so on.

What, the lecturer continued, was the cause of this "beading" which at times was so remarkably prominent in positive ray photographs? Consider, he said, what would happen if the line due to an atom arose in two different ways. Thus in the case of an element the molecule might be split into its atoms whilst still in the discharge tube, and in that case each atom would possess the normal energy when it entered the channel through the cathode. The atoms would thus be able to come up to within a certain distance of the vertical through the centre spot. If, on the other hand, a molecule split into its atoms after attaining the cathode, the normal amount of energy acquired by the molecule would be divided between the two component atoms. Thus at the best an atom of hydrogen thus produced could not get within less than twice the normal distance of the vertical through the centre spot, and would load up, in this neighbourhood, the line due to atoms which had been broken off

the molecule whilst the latter was still in the discharge tube. A more complicated case arose when the discharge tube was filled with, say, CO. Each molecule of this gas would acquire, in the discharge tube, the normal amount of energy. If, however, after entering the passage through the cathode, it split up, this energy would be divided up between the constituent atoms in the proportion of 12 to 16, the carbon atom proceeding through the deflecting fields with $\frac{12}{28}$ of the normal energy, and the oxygen atom with $\frac{16}{28}$ of the normal energy. Hence the lines produced by carbon and oxygen atoms which had acquired normal energy in the discharge tube, would be loaded up or "beaded" at points corresponding to the above respective amounts of energy. Actual measurement showed that beads existed on these lines at exactly the points in question.

We had here, Professor Thomson continued, a method of determining the origin of certain lines. When these started some distance back from the normal position they were due to atoms which had been broken off a compound, and we were thus in a position to say that certain elements were capable of forming compounds hitherto unknown to the chemist. For example, one helium atom was not commonly supposed to be capable of uniting with another helium atom to form a double molecule. Nevertheless, on certain plates (though very rarely) it was found that the helium line was set back to double the normal distance from the vertical through the centre spot. This showed that in certain circumstances two helium atoms could unite together and subsequently break up. Mercury, again, was not supposed to be capable of forming molecules consisting of more than one atom, yet in the discharge tube mercury lines had been obtained showing that it was capable of forming molecules corresponding to an apparent atomic weight of 400. By studying the plates in this way it was possible to extract from them a good deal of information as to the chemical characteristics of different substances.

In certain cases a plate showed parabolas due to particles negatively charged. These negative charges must have been acquired (after the particle had passed through the cathode) by collision with molecules of the gases present. Only comparatively few elements had been found capable of picking up these negative charges. In most cases they corresponded to elements recognised as electro-negative, such as oxygen and chlorine; but particles of bodies not usually recognised as electro-negative were also found on the negative side of the photographs. Amongst them might be mentioned the hydrogen atom, which was found with a negative charge on practically every plate. Carbon was also found with a negative charge on most plates, and neither of these two elements was commonly recognised as electro-negative. When the discharge was passed through hexane, not only carbon but CH was found to reach the target with a negative charge. So did oxygen and OH. A molecule consisting of three atoms of carbon was also found on the negative side. In general, however, atoms were found to acquire negative charges more readily than molecules. Thus, whilst a negatively charged hydrogen atom left its trace on every plate it was rare to find the hydrogen molecule negatively charged. Again, whilst the line made on the negative side by the oxygen atom was always strong that due to the negatively charged oxygen molecule was much more faint. Only two instances were known, as yet, of compound molecules carrying negative charges. These were molecules of CH and of OH. That hydroxyl might carry a negative charge was not strange, but the speaker did not, he said, know enough about CH to say whether chemists had any reason to think it a molecule likely to carry a negative charge.

In Fig. 6 it would be seen that there was a great difference in the lengths of the lines visible, and, indeed, in some cases certain lines were reduced to mere spots whilst others were of considerable length. A long trace implied a wide range in the energy carried by a particle, whilst a short line meant that all the particles of that particular kind had acquired, in the discharge tube, substantially the same amount of energy. Practically the whole of the fall of potential in a discharge tube took place between the "negative glow" and the cathode. The constituents of a molecule which was split up beyond the negative glow would thus all come through the cathode with the same amount of energy, which was the maximum possible. Such particles would, therefore, be concentrated at the heads of the parabolas, and if we got, as sometimes happened, a mere spot here and not a very long line, it followed that the particles producing it all came from beyond the negative glow, and had not been produced in the dark space between this negative glow and the cathode. By studying the length of the lines recorded in a plate it was possible accordingly, to derive information as to the place in which the particles originated and as to the chemical processes going on within the tube.

THE WORKER AND UNEMPLOYMENT.

By JAMES T. BROWNLIE, *Chairman of the Executive Council of the Amalgamated Society of Engineers.*

UNEMPLOYMENT is the bane of our industrial system. It was Carlyle who said that "Workmen fear unemployment more than they fear the wrath of God." The Sage of Chelsea, being the son of a working stonemason, was not without actual experience of the miseries and privations which are inflicted upon the household as a result of the bread-winner being thrown out of work. It is only those who have gone through this awful and depressing experience that can fully appreciate the desolation that enters into the soul of the poor "o'er-laboured wight," as he trudges from workshop to workshop seeking and begging for leave to toil. It is the damnable fear of being thrown out of employment that makes the workers adverse to the introduction of any change in the methods of manufacture that is calculated to expedite output, and not from any real desire to hinder, in any way, increased production whereby the material essentials of life may be produced in abundance, to enhance the comfort of all. Workmen are opposed, and they are not without justification for their opposition, to increasing production to swell the already swollen profits of the profiteers, and are striving to establish a more exalted industrial objective than the production of goods for profit. They hold that the final object of industry should be to get a good method of distribution and a great quantity of consumption, or, as Ruskin puts it, "to use everything and use it nobly, whether it be substance, service, or service perfecting substance."

Broadly speaking, under normal conditions, national and international, depression in trade may be said to be due more to under-consumption, and not, as ofttimes stated, over-production. In other words, the main cause of unemployment may be tersely stated thus: Under existing conditions of wealth distribution, production outstrips consumption so that in the course of time there is a glut of commodities on the market which cannot be immediately disposed of at a profit to their possessors, with the inevitable result that production slows down and workmen are thrown out of employment, notwithstanding the fact that millions of workers and their families are in dire need of the commodities which the labour of the workers has produced. If the consuming powers of the workers were increased, i.e., by higher earnings, thereby bringing consumption on a level with production, an equilibrium would be effected and employment stabilised.

There is no valid reason why industry should not be organised in such a way as to provide full and constant employment for all. The present system of organisation, or lack of organisation, which is responsible for periods of industrial activity being followed by periods of industrial depression, is a sad commentary on the statesmanship of our captains of industry. The organisation of industry on just and humanitarian lines must be tackled in a way that will not only put an end to these recurrent periods of trade depression and unemployment, but will give to the workmen, through their directly chosen representatives, a share in the control of industry, if industrial unrest is to be allayed and the workmen give of their best. Whatever may be the future structure of society, we cannot afford to ignore present-day facts. The most fearful and appalling fact, from the workman's view-point, is unemployment, or his lack of the means to provide himself and his dependants with the requisites of life when out of employment.

In a paper which the writer recently submitted to a conference of representatives of working-class associations, the issue was raised as follows: "Why should not responsibility for unemployment be thrown entirely on to the shoulders of the employing classes who control and organise industry, and who claim the profits partly as a compensation for the risks they take and partly as a payment for their organising skill? It is maintained that some industries cannot be run without a reserve of labour; but if the reserve is to suffer while it is standing idle, the employers are shifting some of the risks of industry—for which they themselves are compensated—on to the shoulders of the workers. Again, unemployment is often due to defective organisation, and if the employers are to be paid for organising skill, there is no great hardship in asking them to bear the losses involved by the lack of it. Now I think that if each industry were responsible for the cost of unemployment, it is practically certain that unemployment would diminish, with enormous gain not only to the workers but to the community in general."

There is before Parliament an Unemployment Insurance Bill which provides that workmen who may be unemployed in specific trades shall receive 15*s.* per week, or 2*s.* 6*d.* per day for a given period. This amount is totally inadequate in present circumstances. There is provision in the Bill which gives an opportunity to industries to contract out of the general scheme by setting up "special schemes" of their own, giving equal or superior advantages, such as may be approved by the Minister of Labour. Here is an excellent opportunity which should be embraced by the representatives of the employers and the workpeople to meet and consider the matter with a view to formulating a "special scheme." It should not be impossible for the representatives of the respective parties to draft an acceptable scheme that would be in many respects superior to the general scheme proposed by the Government, inasmuch as a special scheme prepared by a well-organised industry, employers and workpeople alike, could be administered more economically than the Government's general scheme. Such a scheme would, at least, be free from the blighting influence of bureaucratic control, as it would be managed and administered locally and centrally, by the direct representatives of the parties concerned.

In a very interesting and instructive article which appears in the current issue of *The National Review*, from the pen of Sir Vincent Caillard, on "Industry and Production," there is evidence that he, at any rate, is alive to the paralysing fear of unemployment, and its deterrent effect on production and of the necessity of something being done to remove the not unnatural anxiety from the heart of the workman. He says: "There is, further, the natural and disturbing fear that over-production will come about, with its accompanying crisis of unemployment and distress—and that even without over-production the introduction of labour-saving machinery may, at any rate for a time, cause a similar crisis. This is a fear which has not been sufficiently realised by employers, and which they should meet and eradicate at once. It should not be impossible to devise a general scheme of insurance sufficient fully to cover the risk of unemployment, and remove finally from the heart of labour the paralysing weight of anxiety which is now a very heavy drag on the development of industrial production. If this were done, and their place in the sun assured in the way of a living wage and in the settlement of hours of work—*e.g.*, the 48-hour week—so as to leave the reasonable leisure to workers to which they are undoubtedly entitled, we should have gone far towards clearing the sky." If British industries are to recover the effects of the war; if national and industrial prosperity is to obtain; if the cost of living is to be reduced and exports and production increased, it is imperative that representatives of employers and workpeople should come together to settle this baneful question of unemployment.

THE LATE MR. ANTHONY GEORGE LYSTER.

IT will be with deep regret that a large circle of engineers will hear of the death, on Wednesday last, of Mr. Anthony George Lyster, whose name is widely known in connection with harbour and dock engineering. Born on April 6, 1852, Mr. Lyster was the second son of Mr. George Fosbery Lyster, M.Inst.C.E., of Gisburne, Liverpool. Mr. Lyster was, therefore, only 68 years of age at the time of his death.

The major portion of Mr. Anthony Lyster's life was spent in close connection with port developments on the Mersey, the father and son between them being responsible for the greater part of the improvements at this port over a period of well over fifty years. Mr. G. F. Lyster was appointed engineer to the Mersey Dock Estate in 1861. The son was educated at Harrow, and subsequently continued his education at Bonn under a private tutor. He served his pupilage under his father in the office and on the works of the Mersey Dock Board. He was also about this time for some time in the drawing office of the Elswick works of Sir W. G. Armstrong and Co., Newcastle-on-Tyne, which experience was doubtless of great assistance to him in connection with the hydraulic machinery installations at the new works then being put in hand at Liverpool, and equipped hydraulically by Messrs. Armstrong. In 1873 the Board obtained powers to carry out very large improvements, estimated at about four millions sterling. These were enlargements and alterations recommended by Mr. G. F. Lyster, and included two main groups of works. The so-called northern extension comprised the enlargement of the Canada Basin and the construction of new docks of a water area of over 83 acres, and quayage of over four miles. These works included the Hornby, Alexandra and Langton docks, with their branch docks, locks, &c. The remainder of this scheme was known as the southern extension, and resulted in the addition of over 27 acres of water area and nearly two miles of new quayage being added to the facilities at the port. Thus the whole project was for an increase in water acreage of about 100, with six additional miles of quay. The former increased the existing area of the port by about 40 per cent., and the latter by about 35 per cent.

From 1877 till their completion Mr. A. G. Lyster was in charge of the construction of these works. They formed, as we have shown, a notable addition to the available accommodation on the Mersey. The father was responsible for their design, and gave a comprehensive account of the undertaking in a paper he read before the Institution of Civil Engineers in 1890. It is interesting to note that Mr. A. G. Lyster, about this time, invented a novel type of crane, originally intended for use with grain elevators. The idea at first was to use a movable type of grain elevator to clear ships over side into barges. Mr. Lyster's plan was to place the elevators on the roof of the dock shed, so that they would be out of the way, but could be moved to any spot along the berth, the elevator proper being suspended from a crane running on the roof. The elevator part of the scheme was not adopted, simply because shipowners at the port of Liverpool were required to find such appliances themselves; but roof cranes of a capacity of 30 cwts., on Mr. A. G. Lyster's principle, were adopted, and resulted in greatly increased tonnage per lineal yard of quay.

After holding the position as Assistant Engineer to the Mersey Dock Board for some time, Mr. A. G. Lyster followed his father and held the position of acting engineer-in-chief, from 1890 till 1898. In the latter year he was made engineer-in-chief, which position he retained till 1913, when he resigned to become a partner in the firm of Sir J. Wolfe Barry and Partners, Westminster. While Mr. Lyster was acting chief engineer, the entire reconstruction of two large groups of docks was undertaken, involving expenditure to the amount of three and a-half millions sterling. During the latter part of his time in Liverpool Mr. A. G. Lyster was responsible for the design and construction of the Gladstone Dock, which, however, was actually completed by his successor, Mr. T. M. Newell. These works have been fully described in ENGINEERING and there is no need to enlarge upon them now. His name will also always be associated with the Mersey estuary revetment scheme. It may be mentioned that, excluding work at Birkenhead, something in the order of 13 millions sterling was expended by the Mersey Board on dock works for which Mr. G. F. and Mr. A. G. Lyster were responsible, between 1873 and 1913, the son remaining consulting engineer to the Mersey Dock Board till the time of his death.

Under Mr. A. G. Lyster sand dredging was adopted on a large scale in connection with the Mersey Bar. After the use of some extemporised plant, in 1893 the suction dredger Brancker of 3,000 tons was built. This was the largest hopper suction dredger at that time. The hopper discharging arrangements were on a system designed and patented by Mr. A. G. Lyster. From that time onwards suction dredging was more and more largely adopted on the Mersey, and finally resulted in the development of the Leviathan, a dredger of 10,000 tons hopper capacity, built by Messrs. Cammell Laird and Co. in 1908 to Mr. Lyster's designs.

He was elected a member of the Institution of Civil Engineers in 1882, and was President of the Institution in 1914. In his address he made a departure from usual practice, since, as he himself remarked, the two engineering topics which he was best in a position to discuss had been dealt with by others only a few years previously. His presidential address, therefore, instead of being devoted to dock construction, &c., dealt with harbour and port management, a subject for which his long experience with so progressive a port as the Mersey pre-eminently fitted him. His knowledge of the working of ports and harbours was called into play on wider subjects when he was appointed, in 1908, a member of the International Technical Commission for the Suez Canal. He was also consulted with regard to improvement of New York Harbour and later with Bombay, Port Elizabeth, Shanghai, &c. Mr. Lyster also was a member of the Admiralty Committee on Naval Works at Doon and Rosyth, of 1913. He was also Associate Professor of Engineering at Liverpool University.

Photograph by Thos. Fall.

THE LATE MR. ANTHONY GEORGE LYSTER, M.Eng.

INDUSTRIAL NOTES.

LECTURING last week in the Department of Industrial Administration of the Manchester College of Technology Mr. Percy J. Pybus, C.B.E., one of the managing directors of the English Electric Company, said that increased production was a cry with which we were all familiar. Reviewing the objections of the trade unions to increasing output, he said that it was a doctrine which was repudiated by many trade unionists and by almost all the responsible labour leaders, but it was impossible to contest the extent of its influence on the rank and file. It had its origin in the dread of unemployment. The group-bonus system, Mr. Pybus continued, was radically unsound, and its adoption as a solution to our present troubles would only intensify them. The relative popularity with the engineering unions of systems such as the Priestman bonus system in itself excited suspicion. The support given by district branches of those unions was consistent neither with their declared objections to payment by results nor with the advocacy of many of their leaders of idleness as a political principle. From the point of view of the men such systems represented "money for nothing." The good worker shared the result of his exertions with his colleagues, while the slacker distributed the results of his idleness over the shop. Mr. Pybus subsequently briefly outlined a scheme which was successfully working in a modern factory, and said the reason for its success lay in the fact that the whole question of rate-fixing was brought into the light of day and revealed its true character as an open bargain between the workmen and the employer. A rate was fixed for a new job and offered to the man concerned. He was at liberty, if he questioned it, to go to the time study office and work through the calculations with the responsible official. If still unconvinced he could refer to a committee which had to meet within two days of the complaint. Pending its meeting the firm's rate was given effect to, and the decision of the committee when given was retrospective, and no figure as to the time taken on the job between the fixing of the rate and the meeting of the committee was taken as evidence before the committee. That body consisted of three representatives of the firm and three of the men, one of whom was the workman concerned, and the other two were selected by him as being on similar work. If the committee failed to agree the firm was called upon to demonstrate in its own works that the rate was fair. It was open to the firm to use the machinery for reviewing a rate which they thought too high, but any reduction was compensated by an equivalent addition to the rate for some other job less favourable to the men.

An award issued on the 10th inst. contains the decision of the Industrial Court on the application of the trade unions connected with the engineering trades for an advance in wages. It has been the practice since early in 1917 for an arbitration tribunal to review the wages position in the engineering trades every four months. The authority for this purpose was previously the Committee on Production, and later the Interim Court of Arbitration. These bodies no longer exist, and on the occasion of the recent hearing in February the matter came before the Industrial Court. The claims of the unions were, in general, for an advance of 15*s.* a week to men and 10*s.* a week to youths and boys. The decision of the Court refers to the fact that in December last the men obtained an advance of 5*s.* a week as the result of an award of the Interim Court of Arbitration, largely on the ground that an increase in prices was expected to take place during the winter months. That expectation appears to have been partially fulfilled, the official index number of the cost of living having advanced from 120 above pre-war level in October last to 130 at the present time. The Court now hold that the men's claim on the ground of cost of living fails. The awards of the Committee on Production and Court of Arbitration were given principally on the ground of changes in the cost of living. The decision of the Industrial Court on this occasion points out that while, during the exceptional circumstances of the war, it was proper to take into account the cost of living as the principal determinant of wages other considerations now arise. It expresses the view that the remuneration of the workpeople should depend on the value of the work done and that the value of the work done depends on the state of the market. It proceeds to point out the engineering trade is in a condition of exceptional activity owing to the need for repairing the loss and wastage of war. It also refers to the fact that the rates of the men concerned have, apart from advances to meet the increased cost of living, remained unchanged for several years, to the relationship between the wages in the engineering industry and those in other trades, and the desirability of stabilising the position in the industry for a reasonable period. Having regard to these various considerations, the Court have decided on an advance of 6*s.* a week on the time rates of men 21 years of age and over and an advance of 15 per cent. on piece-work prices. The application of the advance embodies a new principle so far as general awards previously given in the trade are concerned, a provision being made for half the advance to become due on April 1 and the remaining half on June 1. The advances are payable to all workers, irrespective of age, so far as they are employed on piecework and also to labourers under 21 years of age who are customarily paid men's rates. An award substantially similar in terms has also been issued in respect of the shipbuilding and ship-repairing trades.

We have received a copy of the first edition of "The King's National Roll." The book contains about 10,000 names of firms who gave an undertaking for the employment of disabled men under the National Scheme. Since the book went to press the number of employers registered has grown to over 12,000, and the later additions will appear in new editions of the Roll. The total is still growing, but the supply of disabled men is unhappily by no means exhausted. There are thousands yet to leave hospital, all of whom will have to be found livelihood employment.

The Executive Committee of the Miners Federation at a meeting of delegates in London on the 12th inst. reported on the wages position and on their recent interview with the Prime Minister regarding the proposals of the Miners' Federation to reduce the price of coal. Those proposals having been refused by the Prime Minister, the committee advised the conference to make application at once for an advance in wages of 3*s.* per shift for all members of the Miners' Federation over 16 years of age, and 1*s.* 6*d.* for those under that age. By an overwhelming majority the conference accepted the recommendation, and agreed to put forward an application for this advance to date from the first of the present month. It was also decided to adjourn the conference until March 24, to receive the committee's report on the application. It is estimated that this advance in wages will mean an addition of about 45,000,000*l.* to the annual wages bill of the miners. The shift is 7 hours, and one winding. Overtime being measured by the shift, an increase in wage per shift will lead to a corresponding increase in the rate for overtime. The South Wales miners are disappointed at this advance of 3*s.* per shift, since their demand was for an advance of 2*l.* per week, but it is stated that they will abide by the national demand.

In Parliament, last Tuesday, Mr. Kellaway, the Deputy Minister of Munitions, in reply to a question as to whether he could state the number of wagons ordered to be built at Woolwich Arsenal and the average number turned out per week, said the number ordered was 2,500; as to the rate of delivery, this had been adversely affected by the moulders' strike, but during the week ended the 10th inst. 11 wagons were completed, and it was hoped to increase the rate of production in the course of the next few weeks.

It is reported that the Triple Alliance, which, as is well known, includes the miners, railwaymen, and transport workers, may be extended and form a Quadruple Alliance by the inclusion of the engineering unions. The scheme, it is added, is to be considered at a meeting of all the unions concerned to be held shortly.

THE SURVEYOR'S INSTITUTION.—This institution, whose offices are at 12, Great George Street, Westminster, S.W. 1, has issued a small booklet giving its scale of professional charges for valuation of properties, valuation for probate or estate duty, &c. We may add that Mr. Howard Martin, one of the past-president of the institution, has accepted office as the first official arbitrator appointed by the Reference Committee under the Acquisition of Lands (Assessment of Compensation) Act, 1919.

BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION.—Reference was made to this association at the recent meetings of the Institute of Metals. The association has recently been established in the interests of British manufacturers and users of ferrous metals. A first meeting of manufacturers was held in Birmingham in December, 1917, when a provisional committee was formed. Articles were drafted, and a certificate of incorporation was only granted on January 21 last. The association is a national one; it has the support of the Government Department of Scientific and Industrial Research. Birmingham has been selected for the headquarters, as being the centre of the British non-ferrous metals industry. The association embraces the whole of that industry and includes producers, manufacturers and users. Its objects are to act as a channel for the direct application of existing scientific and technical knowledge by means of its bureau; to conduct industrial research so as to utilise the results of scientific discovery; and to conduct pure research to add to existing knowledge. The secretary's offices are at 29, Paradise-street, Birmingham.

THE ART OF CASTING IN HIGH TENSILE BRASS.*

By NEIL J. MACLEAN (Glasgow).

EARLY in 1916 the writer's firm took up the manufacture of a new line of precision instruments for naval use, in which several of the castings were specified to be of "manganese-bronze," as the alloy is usually named, or high tensile brass, as it might better be termed. At that time the output was about 6 tons of castings per week in the foundry—4 tons of Admiralty gun-metal, 1 ton of yellow brass, and 1 ton of miscellaneous alloys. The limited experience previously obtained of castings in phosphor or manganese bronze had not been at all successful, and the prospect was somewhat perplexing of suddenly fulfilling this new requirement in the midst of the stress of that very strenuous time. The firm which was making these instruments stated that they had turned out large quantities of castings in the specified alloy, that it was quite easy to work in and could be relied on to give an ultimate strength of 40 tons per square inch. They were therefore asked to supply the castings meantime, which they agreed to do, but upon testing, the first batch of castings gave breaking strengths as low as 12 tons per square inch. The test bars were made from the castings themselves. The matter was referred to the firm for an explanation, who replied that, as the castings had passed the Government inspector at their end, there was no need for further discussion.

The question was then considered of obtaining supplies of the castings from one of the firms which specialised in these high tensile yellow alloys, but as the result of correspondence and conversations with their representatives, the conclusion was reached that in speaking of strength qualities they had in mind results obtained with chilled—or otherwise manipulated—test bars, and also that the figures which they quoted as applying to any particular cast metal were not the guaranteed minimum but more nearly the hoped-for maximum figures. An example of what is meant is illustrated in Figs. 11 and 12, on page 391. A pattern of this casting was sent to a firm who claimed that their manganese-bronze gave 42 tons per square inch and 23 per cent. extension on test-pieces selected from a number at random. The test-piece within the casting gave 19 tons tensile and 3 per cent. extension; the chilled test-piece cast outside the casting by the makers at their own suggestion gave 29 tons tensile and 27 per cent. elongation. Thus the casting itself had strength properties inferior to Admiralty gun-metal, while the manipulated test bar gave results much below the makers' claims.

The firm did not feel at all satisfied with this position, and in consequence decided to investigate the whole question for themselves, and though definite conclusions have not yet been reached on all the points raised, the experience gained may be of sufficient general interest to bring it before you at this stage. The writer has, throughout the experiments, consistently kept in view the practical foundry aspect of the whole question, and has only considered those results as worth while which could be embodied in daily foundry practice. For this reason it was decided at the outset that the test bars (see diagram 9) must be cast along with the casting which they were supposed to represent and under exactly the same conditions, without chilling or manipulation of any kind, and also that an alloy would not be considered as having specified strength properties unless it could be guaranteed to turn out castings having those properties every time, with a reasonable percentage allowance of failures.

In order to give definite shape to the inquiry the following specification of strength was fixed upon as the goal, and the quest of methods was set out upon which would enable castings to be turned out regularly, cast in sand moulds, whose strength could be guaranteed not to fall below these figures:—

Ultimate strength	20 tons per sq. in.
Elastic limit	10 tons per sq. in.
Elongation on a length of 2 in.	15 per cent.

It will be remembered that the corresponding figure for Admiralty gun-metal are:—

Ultimate strength	14 tons per sq. in.
Elastic limit	7 tons per sq. in.
Elongation on a length of 2 in.	7·5 per cent.

So that the problem to be solved was, roughly, to produce an alloy with 50 per cent. better qualities than the one at that time chiefly used.

The first series of experiments was with a brass made from metals of ordinary commercial purity and containing either 1 per cent. or 2 per cent. or 3 per cent. of manganese. As the high manganese alloy gave on the whole the best results, this was adopted and worked regularly in for some weeks. Diagram 1 shows a series of results with this alloy. They were promising, but the elastic strength was disappointing. In this diagram, and in those which follow, each point on the curve represents the physical properties of one test bar, cast in green sand. Four test bars were cast in a box and turned to sizes shown on the sketch; the bar which on being broken gave the best result was chosen as the bar to be figured on the chart. The chemical composition aimed at is given in the column below the test-bar readings. The elastic limit is the term which correctly defines the figures measured in these tests, the figures were obtained by placing a straight-edge along the stress and strain curve, and marking the point where that curve ceases to be a straight line. This point marks the limit beyond which strain increases out of all proportion to stress, and therefore the test-piece if stressed beyond this point ceases to be elastic. Great importance was attached to this particular property of elastic strength, as the castings to be made

* Paper read before the Institute of Metals, March 12.

THE ART OF CASTING IN HIGH TENSILE BRASS.

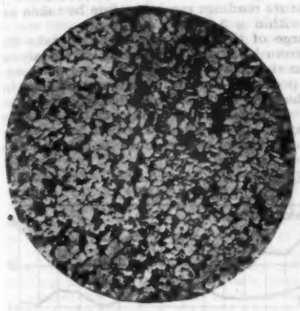


FIG. 1.

FIG. 2.

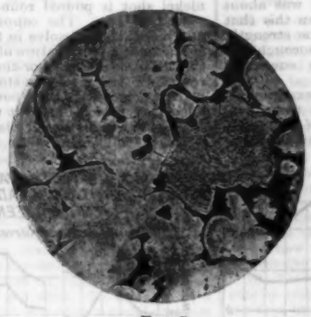


FIG. 7.

FIG. 8.

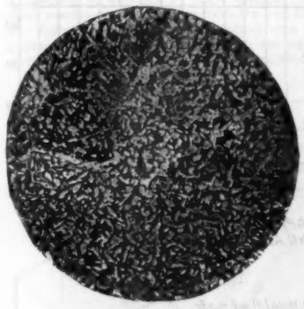


FIG. 3.

FIG. 4.

FIG. 9.

FIG. 5.

FIG. 6.

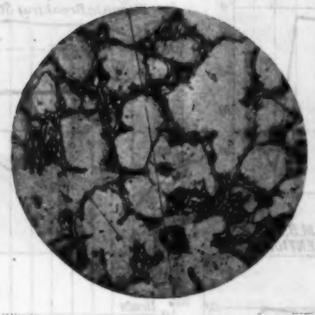


FIG. 10.

KEY TO PHOTOMICROGRAPHS.

Solution—[Fe_2Cl_6 (concentrated solution), 50 c.c. + 15 drops HCl (concentrated) + H_2O (distilled)] = 100 c.c.

Fig. No.	Magnified.	Objective.	Composition. (A) By Analysis. (N) Nominal. Cu.	Zn.	Ni.	Fe.	Pb.	Sn.	Mn.	Al.	Results of Tests. Elastic Limit, Tons per Sq. In.	Breaking Stress, Tons per Sq. In.	Elongation per Cent. on 2·0 In.	Scleroscope Hardness.	Brinell 500 Kg.	—
1	× 30	Winkle ⅔ in.	(A) 53·19	34·2	9·04	1·45	0·08	0·11	1·56	0·35	15·0	33·0	37·0	22·0	114·0	German submarine, periscope tube.
2	× 100	Watson ⅙ in.	53·19	34·2	9·04	1·45	0·08	0·11	1·56	0·35	15·0	33·0	37·0	22·0	114·0	
3	× 30	Winkle ⅔ in.	(A) 57·29	40·0	—	0·75	Trs.	—	1·92	Trs.	9·7	29·0	30·0	18·5	—	(13 M.B.).
4	× 30	,,	(A) 55·02	41·9	—	0·75	Trs.	0·15	2·04	·009	13·5	34·0	16·0	21·0	143·0	(10 M.B.).
5	× 30	,,	(N) 60·0	34·0	3·0	2·0	0·5	0·25	0·25	—	11·0	30·0	33·0	18·0	100·0	(Good result.) (II., M.B. 42) (Routine)
6	× 30	,,	(N) 60·0	34·0	3·0	2·0	0·5	0·25	0·25	—	9·8	25·0	13·0	17·5	—	(Poor result.) (II., M.B. 43) (Routine).
7	× 150	Watson ⅙ in.	(N) 58·8	34·0	3·0	2·2	1·3	0·4	0·3	—	10·0	27·0	40·0	—	—	(a) (II., M.B. 216) (Routine).
8	× 150	,,	(N) 58·0	34·0	3·0	3·0	0·3	1·0	0·3	0·4	12·0	28·0	20·0	—	—	(b) (II., M.B. 179) (Routine).
9	× 150	,,	(N) 59·0	34·0	3·2	2·0	0·8	0·7	0·3	—	12·0	28·0	33·0	—	—	(c) (II., M.B. 205) (Routine).
10	× 150	,,	(A) 58·48	35·00	2·35	1·60	0·62	1·89	0·03	—	11·0	19·0	6·0	15·0	93·0	(d) (II., M.B. 259) (Routine).

are generally very light in section, and one of the chief difficulties is to machine them to accurate sizes without distortion, due to the cut or to clamping. In resisting distortion a high elastic strength is the principal quality in question.

A second series of experiments was then made in which different elements—vanadium, titanium and cadmium—were added to the alloy, which was otherwise kept the same as the resultant of the first series. Trouble was experienced in using these alloys, due to imperfect mixing of the vanadium, &c., in the copper as supplied by the makers, and to the difficulty of melting the alloy copper in the main portion of the charge. The result was a marked improvement in elastic strength but very poor quality in elongation, as shown in Diagram 2, page 390.

As the results were not on the whole very encouraging it was decided to return to the simple manganese-brass, but to try the effect of using pure metals, as the first experiments were with ordinary commercial qualities and contained some lead. Though it was feared that a lead-free alloy might be very troublesome to machine, the writer wished to know the effect on the strength qualities of using the pure metals. The result is given in Diagram 3, page 390, which shows an improvement in elastic strength, but at the cost of the elongation. All these efforts—and the experiments were continued for several months—to discover methods of practical mixing, melting and pouring of this alloy which would yield better results were unsuccessful.

In August, 1918, a damaged German periscope taken from a captured submarine was sent to the works for examination; the outer tube was cut up and a sample analysed, when it was found to be a complex brass containing 9 per cent. of nickel and 1·5 per cent. iron. Figs. 1 and 2, above, are photomicrographs of the alloy, whose percentage composition was:—

	Per Cent.
Copper	53·0
Iron	1·5
Zinc	34·0
Manganese	1·5
Nickel	9·0
Aluminium	0·35

It will be noticed that the physical structure is very good indeed, uniform and fine grained. A series of experiments was carried out as suggested by this alloy, with varying content of nickel, but without definite results. The foundry then worked for some weeks thereafter with the alloy used in the German periscope, with the results shown in Diagram 4. This marked an improvement on previous results, but was very erratic in elongation, and varied considerably in breaking strength.

Further consideration, supported by experiments, led to the conclusion that the high percentage of nickel did not seem to be of any special advantage. Varying the nickel content was tried from 5 per cent. to 9 per cent., but without detecting any consistent tendency to improve the strength properties. It was decided finally to use 3 per cent. of nickel. A set of experiments was next tried which suggested an improvement with increase of iron, as a result of which 2 per cent. of iron was fixed on as giving the most promising results. As the iron could be considered to be taking the place of the manganese the latter was reduced to 1 per cent., and finally a small quantity of phosphor-tin was added as a cleanser. Some tests with this alloy gave very encouraging results, showing it to be more uniform in strength properties than any as yet tried; but the manipulation of the metal still gave trouble, and it was felt that there were several considerations in using it which were not yet understood. Diagram 5 shows the result of these experiments.

As there was a possibility that this alloy, while giving

satisfactory breaking tests, might show poor results under alternating stresses, some test bars were prepared and sent to Dr. Bernard Haig for test by him in his electromagnetic alternating stress machine. These tests showed that, generally speaking, the fatigue strength varied roughly as the elastic strength, and was about equal in value to it. It was concluded from this that the alloy was not notably at fault in fatigue strength, though the tests were not carried far enough thoroughly to explore its behaviour when subjected to continued alternating stresses.

A general review of the whole series of experiments at this stage suggested that the following three considerations affected vitally the properties of the metal as cast, in addition to its chemical composition :—

Diagram 1. SERIES OF ROUTINE M.B. HEATS. (CAST IN GREEN-SAND.)

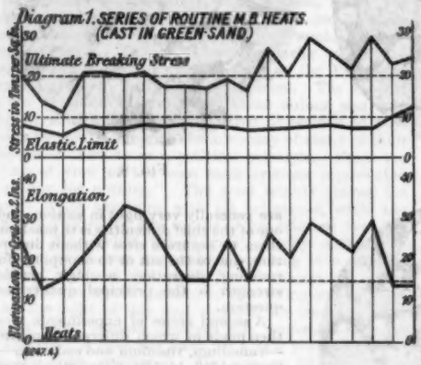


Diagram 2. EFFECT OF VARYING PROPORTIONS OF VANADIUM, TITANIUM, CADMIUM, ADDED TO M.B. (CAST IN GREEN-SAND.)

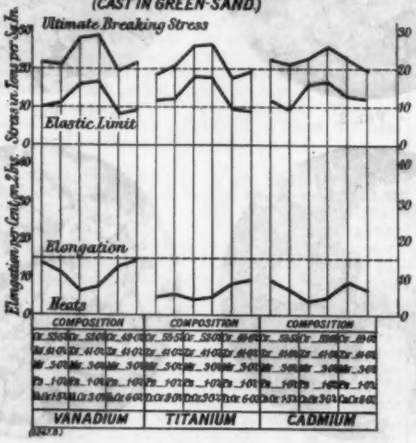


Diagram 3. SERIES OF SPECIAL M.B. HEATS FREE OF LEAD. (CAST IN GREEN-SAND.)

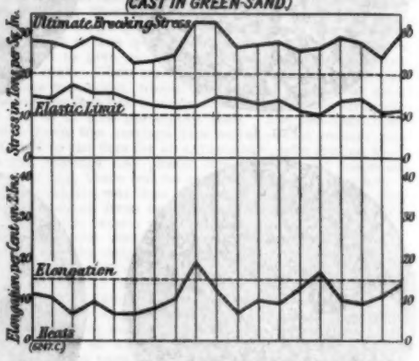


Diagram 4. SERIES OF M.B. HEATS OF SAME CHEMICAL COMPOSITION AS GERMAN SUBMARINE PERISCOPE METAL. (CAST IN GREEN-SAND.)

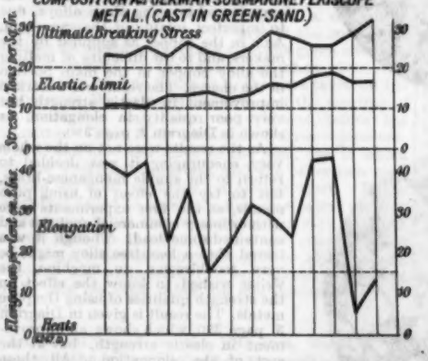


Diagram 5. SERIES OF ROUTINE M.B. HEATS CONTAINING IRON & NICKEL. (CAST IN GREEN-SAND.)

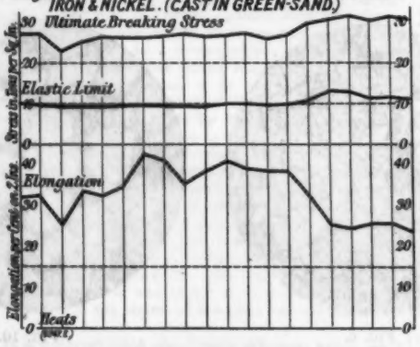


Diagram 6. APPARATUS FOR GRANULATING HARDENING ALLOY USED IN M.B.

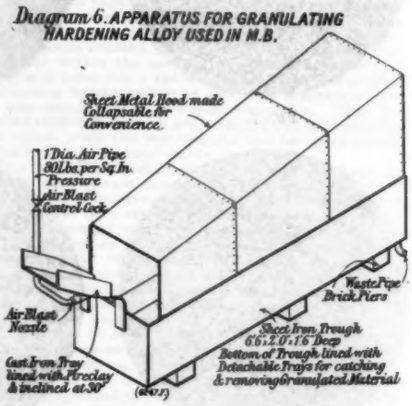

Sheet Metal Hood made Collapsable for Convenience.
1" Dia. Air Pipe 80 Lbs. per Sq. In. Pressure
Air Blast Control Cock
Waste Pipe
Brick Piers
Air Blast Nozzle
Sheet Iron Trough 6'6" x 2'0" x 1'6" Deep
Bottom of Trough lined with Detachable Trays for catching & removing Granulated Material
Cast Iron Tray lined with Fireclay & inclined at 30°

Diagram 7. EFFECT OF TEMPERATURE ON M.B. ALLOY. CASTING TEMPERATURES IN DEGREES CENTIGRADE.

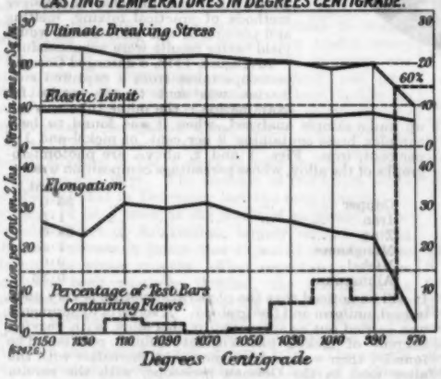

Ultimate Breaking Stress
Elastic Limit
Elongation
Percentage of Test Bars Containing Flaws.
60%
Stress in Tons per Sq. In.
Elongation per Cent. on 2 Ins.
1150 1130 1110 1090 1070 1050 1030 1010 990 970
Degrees Centigrade

Diagram 8. SERIES OF ROUTINE M.B. HEATS FROM OCT. 16 TO NOV. 17, 1919, CONTAINING IRON & NICKEL. ALL TEST-BARS CAST ON CASTINGS.

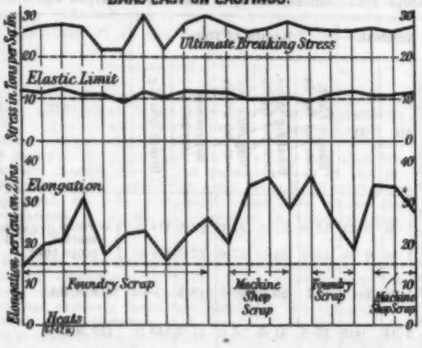
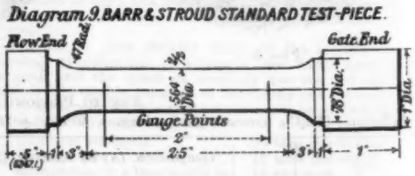


Diagram 9. BARR & STROUD STANDARD TEST-PIECE.



(a) The method adopted to introduce the special metals into the brass when melting the alloy.
(b) Pouring the castings at the correct temperature.
(c) Maintaining the zinc content of the alloy constant.

(a) In the earlier experiments the special elements present—iron, manganese, vanadium, &c.—were brought in as double alloys with copper or zinc; but these were found to be imperfectly mixed and lumpy, and did not prove satisfactory; they did not melt easily in the molten copper nor mix thoroughly throughout the mass. The conclusion was reached that the way in which these special elements were added to the melt was important, and it was therefore decided to experiment in the making up of these alloys. The first trial consisted of melting copper, nickel and iron in the proportions :—

	Per Cent.
Copper	75
Nickel	15
Iron	10

in a crucible, raising this to a height of about 15 ft., and pouring the molten mass into water; but this plan was clumsy and not safe.

After some rough experiments the method finally developed was as follows: Soft iron tie wire is made up into bundles and placed in the bottom of the crucible, nickel shot is poured round it, and copper ingots are placed on top. The copper melts first, and the iron and nickel then dissolve in the molten copper. The pot is drawn at a temperature of 1,300 deg. C. and skimmed; a sn all piece of phosphor-tin is added, causing a vigorous reaction; the molten metal is covered with moulders blacking, and it is then poured slowly on to a fireclay lined tray, which breaks it up into little streams which, when acted on by an air-blast, blow it into a hood from which it falls into water and is quenched. The air pressure used is 80 lb. per square inch, and the nozzle aperture 4 in. by ¼ in. The sketch, diagram 6, shows the arrangement. In this way an intimately mixed and finely-granulated alloy is obtained which melts readily in the copper and mixes quickly throughout the mass.

(b) It is now well established that the temperature at which the casting is poured has a very important effect on the strength of the casting, and these experiments bear this out. Diagram 7 shows that the best pouring temperature is at 1,090 deg. C. ± 20 deg. Outside these limits there is a marked falling off in one or other of the strength qualities. The temperature experiments were carried out as follows. The pyrometer used was a thermocouple instrument made by the Cambridge Scientific Instrument Company, with a platinum, platinum-rhodium thermocouple; this was calibrated against a standard pyrometer of the same make, which was itself calibrated against the melting-points of pure metals through a range from 100 deg. C. to 1,084 deg. C., and the temperature readings may therefore be taken as being correct to within ± 5 deg. C.

A 180-lb. charge of the alloy was found to take 20 minutes to cool from 1,150 deg. to 950 deg. By analysis it was found that the zinc content was about 4 per cent. less in a sample poured at the lower temperature than in one poured at the higher. It was decided, therefore, to carry out the temperature experiments with three separate charges, no one of which was used after being more than 7 minutes out of the furnace; in this way the composition was kept constant to within 1 per cent. of zinc content. The thermocouple was protected by a silica sheath 0·05 in. thick inside a steel tube. The cold junction was encased in an aluminium casting 3 ft. 6 in. from the hot junction. The pyrometer was held by the operator quite comfortably when in use, an asbestos disc protecting the hand from the heat of the furnace; the indicator was placed about 12 ft. from the instrument; compensating leads were used to connect pyrometer and indicator. The pyrometer was immersed in the metal after withdrawing the pot from the fire, and was kept in it during the whole time of pouring. By taking these precautions the instrument lasted during the series of experiments, but it is not thought that immersion pyrometers are yet robust enough to stand up to routine foundry use; they have always broken down when subjected to ordinary foundry treatment.

It was realised more and more clearly as the investigation proceeded that one of the most important factors in determining the properties of the alloy was the percentage of zinc present, and careful examination of different chemical analyses along with photomicrographs of the specimens led to the desirable accuracy of working being fixed at ± 0·5 per cent. The steps taken towards realising this accuracy were: (1) More accurate weighing of the charge. A decimal weighing machine was used sensitive to 0·1 lb. (2) Quicker drawing of the pots from the fire as soon as the charge was melted. (3) Lectures delivered to the furnace workers to try to enlist their interest in maintaining all the working conditions as constant as possible.

Photomicrographs 3 and 4, page 389, show the effect on the structure of the metal of variations in the zinc content. This change of structure is very definite and

is accompanied by marked changes in the strength properties, though the variation in the zinc content is not great. These two photomicrographs are typical of a large number taken which show similar effects.

It has not yet been possible to work within the limits of zinc content laid down, though the results are more exact than when the experiments began. This is one of the everyday difficulties in foundry practice which seems so far to have received but little consideration from scientific societies, and the writer would like to rouse interest in it with a view to eliciting information as to what is the daily practice in other foundries. The most promising direction in which to look for further progress seems to be either in gas or electric melting, in which the heating conditions are more constant and better controlled, and the temperature of the metal while in the furnace could be measured. It is most important that the temperature should be measured and be under control before drawing the pot from the fire, or the damage may be done—i.e., an important fraction of the zinc may be burned off before the furnaceman knows about it. In coke melting under natural draught the weather conditions vary and undoubtedly affect the rate of melting and furnace temperature, and it is impossible to control this variation and maintain uniform conditions.

A general survey of the experiments up to the end of 1918 led to the conclusion that there had been developed a method of casting in high tensile brass which gave good results under regular foundry conditions, but it was not forgotten that if this method was followed closely a practical difficulty would soon emerge, in that there would be a lot of scrap from the machine shop and also from the foundry in the form of gates, risers, &c., which would be a source of loss if it could not be used up. Experiments were therefore carried out on the use of scrap in the charge, and the very satisfactory result observed that the strength properties of the mixed alloy using carefully-collected scrap were not inferior to the results when using new metal. The practical difficulty in using scrap is the danger of hurtful impurities, such as lead and tin, getting into the alloy. To avoid this, very careful handling of the scrap in the machine shop and while on its way to the foundry was arranged for; it was collected by a special man in marked buckets, the machine-shop operators and labourers not being allowed to touch it. This machine-shop scrap was then mixed with the brass gates and risers from the foundry, and the whole melted in a coke-fired furnace in a 400-lb. pot, and run into ingots. The ingots were analysed for zinc content, and the quantity of zinc required to give the correct proportion in the final melt was calculated. The following method was finally developed for making up and melting the charge. About 60 lb. of the scrap ingots are placed in the bottom of the crucible and melted; the hardener of copper, nickel and iron is then added, and floats on the surface; the remainder of the ingots are charged, and when melted the hardener has all passed into solution. About 3 minutes before the pot is drawn from the furnace the correcting zinc is added. By following this method, castings giving the results shown on Diagram 8, on the opposite page, have been turned out during 1919. In Fig. 5, page 389, and Figs. 6 to 10, are shown typical photomicrographs of the alloy with its chemical composition. The structure is uniform and fine-grained. Fig. 6, shows a poor result, probably due to bad mixing of the metals, and Fig. 10, page 389, a poor result, probably due to presence of tin. It will be noted that in no case do the strength properties fall below the limits which were set at the beginning of the investigation. The conclusion has, therefore, been reached that a metal can be cast regularly under ordinary foundry conditions which has strength properties about 50 per cent. superior to Admiralty gun-metal.

It will be interesting to compare the costs of the two alloys, as given in the next column:

Admiralty Gun-metal.

	£
88 per cent. electrolytic copper at 106*l.* per ton	93
10 per cent. pure tin at 245*l.* per ton	24
2 per cent. pure zinc at 70*l.* per ton	1
	£118

High-Tensile Brass.

70 per cent. scrap ingots at 65*l.* per ton	45
20 per cent. hardener at 118*l.* per ton	24
9 per cent. pure zinc at 70*l.* per ton	6
	£75

The cost of the gun-metal has been taken out for pure metals, as these must be used if the Admiralty tests are to be complied with. These costs are made up on the basis of prices as at February, 1919. The price for the scrap brass is that actually paid for some scrap sold in January, 1919. This shows a saving of 43*l.* per ton, or 36 per cent. in the cost of the metal in favour of the high-tensile brass. Assuming that the cost of the casting is about one-half metal and one-half labour and on-cost charges, the saving in the cost of making the finished casting should be about 18 per cent. In the case of a foundry turning out about 100 tons of gun-metal castings per year and taking the cost of 1 ton of castings at 200*l.*, the saving therefore in using high tensile brass instead of gun-metal would be about 3,600*l.*, while the strength properties of the new castings would be better than the old. The question which every practical engineer must ask himself in view of these figures, is, why not abandon gun-metal and adopt high-tensile brass? It is certain that there must be answers to this question, which account for the fact that such a change is not being made, and it will be interesting to learn what these reasons are in the course of the discussion which it is hoped this paper will provoke. It has been tried in this brief account of a series of experiments carried on during the past three years to give the impression that our research was always directed to developing practical foundry methods rather than to obtaining what one might call a laboratory result. There has been a great deal of research work done in recent years on the copper alloys, but there is still a gap between the application of the knowledge so gained and the daily routine work of the foundry, and until this gap can be bridged the improvements indicated in the laboratory experiments cannot be realised in practice. In other words, the production of a casting remains still—as it has always been—much of an art, and only something of a science.

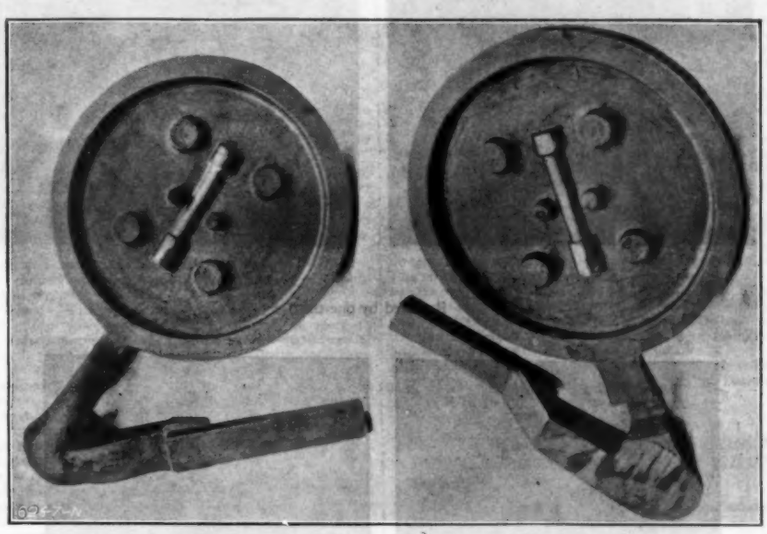


FIG. 11.

FIG. 12.

SUMMARY AND CONCLUSION.

1. Castings in "manganese-bronze" as submitted by firms specialising in that alloy were found to be unsatisfactory, in that they were unreliable in strength properties and failed to fulfil the makers' claims.

2. It was decided to experiment with a view to producing an alloy which, when cast in sand moulds without chilling, could be depended on to give results 50 per cent. better than Admiralty gun-metal.

3. Experiments were made first with a single brass containing manganese; to this in turn were added vanadium, titanium, cadmium, and, later, nickel and iron. The results were at first erratic, but gradually became more reliable.

4. The alloy finally chosen, after trying a large number, consisted of:—

	Per Cent.
Copper	60·0
Zinc	34·0
Nickel	3·0
Iron	2·0
Lead	0·25
Manganese	0·5
Phosphor-tin	0·25

5. A special hardener was made consisting of:—

	Per Cent.
Copper	75·0
Nickel	15·0
Iron	10·0

This was melted in a crucible and granulated by blowing a stream of the molten alloy into a tank containing water.

6. Special precautions were taken to keep the zinc content of the alloy constant by careful weighing of the charge, temperature control of the charge while in the furnace and instructions to furnacemen on their duties.

7. Special precautions were also observed in keeping the pouring temperature of the alloy constant by temperature control after removing the crucible from the furnace.

8. Scrap metal consisting of foundry scrap, leads, gates, &c., and machine-shop scrap was carefully collected and melted down into ingots. Each ingot was analysed and the quantity of zinc required to correct for zinc content noted.

9. The charge was finally made up, using some scrap, some new metal, a quantity of hardener, and zinc to correct the zinc content.

10. This alloy, when properly melted and poured, can be relied upon to give sound castings, cast in sand moulds, having a breaking strength of 20 tons per square inch, elastic strength 10 tons per square inch, and elongation 15 per cent. on a length of 2 in.

In conclusion, the writer desires to acknowledge the help that he has received, throughout these experiments, from his assistant, Mr. Summers, without whose patient and persistent work in the foundry such progress as has been recorded here could not have been made.

SOME NOTES ON THE EFFECTS OF HYDROGEN ON COPPER.*

By W. C. HOTHERSALL, M.Sc.Tech. (Manchester), and E. L. RHEAD, M.Sc.Tech., F.I.C., Member (Manchester).

THE present notes deal with experiments carried out in the early part of 1914 to determine the effect produced by the passage of hydrogen through molten copper, on the properties of the copper when cast. The work was interrupted by the war, but it is thought that the publication of the results obtained so far may be of interest.

Copper Used.—Four types of copper were used in these experiments: (1) Copper containing a comparatively high percentage of arsenic (0·5 per cent.) and a low percentage of sulphur (0·04 per cent.); (2) copper containing a comparatively low percentage of arsenic (0·05 per cent.) and high percentage of sulphur (0·1 per cent.); (3) copper as in (2), but with additions of various amounts of arsenic (up to 0·4 per cent.) and sulphur (up to 0·4 per cent.); (4) electrolytic copper.

Method of Treatment with Hydrogen.—The copper was melted down in a closely-covered fireclay crucible in a wind furnace to avoid oxidation, about 1 lb. of copper being used for each melt. The hydrogen used was the commercial product sent out in cylinders, and was bubbled through the molten copper for 15 minutes by means of a silica tube passing through the lid of the crucible. The amount of gas passed was not measured. The temperature of the copper was taken immediately before treatment by means of a carefully standardised Féry pyrometer clamped about 8 ft. directly above the crucible. Samples of copper for analysis were taken immediately before and after passage of the hydrogen. Immediately after the passage of the hydrogen the surface of the copper was covered with wood charcoal to prevent oxidation.

Method of Casting the Copper.—The copper was cast in sand moulds in the form of round bars, 6 in. long and ½ in. diameter, the bars being cast on end. Bars of untreated copper of the same type were also cast for comparison, the copper being melted down under charcoal and kept molten for 15 minutes before casting. Any difference in properties between the treated and untreated copper may therefore be considered as due to some effect of the hydrogen other than mere deoxidation.

Difficulty was at first experienced in obtaining sound bars of copper, especially in the case of the copper treated with hydrogen. This difficulty was ultimately overcome in the case of the treated copper by allowing the molten copper after treatment to solidify under charcoal in the furnace and then remelting and casting. In this way sound bars of treated copper were obtained.

This method was not efficacious in the case of untreated copper, or of copper which had been allowed to oxidise, and had subsequently been deoxidised by charcoal. There thus appears to be an important difference between the solubilities of hydrogen and carbon monoxide (the gas that was apparently the cause of the unsoundness of the bars of untreated copper) in solid copper or in molten copper at or near the solidifying temperature.

Temperature of Treatment.—The temperature of the copper at the commencement of the passage of hydrogen varied between 1,110 deg. and 1,140 deg. C. In one case the copper was treated at a temperature just above the melting-point, but an unsound bar was obtained; after treatment at the higher temperature, however, the copper cast soundly. This appears to indicate that the temperature of treatment is important.

Condition of Cast Bars of Treated Copper.—All the treated bars after solidification and remelting described above cast sound and clean, those containing a small percentage of arsenic having a deep pipe in the upper end; in the bars of impure copper this pipe was lined with well-developed octahedral crystals of copper, while in the case of electrolytic copper the crystals were absent. A high percentage of arsenic (0·4 per cent. to 0·6 per

* Paper read before the Institute of Metals, March 12.

cent.) prevented the formation of this pipe; the crystalline nature of the copper was evident on breaking the bar.

Chemical Composition and Physical Properties of Treated and Untreated Copper.—The copper was analysed before and after treatment with hydrogen, and treated and untreated bars were subjected to tensile tests, micrographic examination, and determination of the specific gravity and electrical conductivity. The methods of test employed are described in the Appendix, the results obtained being given below:—

Class.	Bar.	Treated or Untreated.	Percentages of Impurities. Sulphur.	Arsenic.	Antimony.	Bismuth.	Hydrogen.
1	Average of 7 bars	2 before treatment	0·038	0·60	0·066	0·017	Not estimated.
		5 after treatment	0·036	0·57	0·058	0·016	
2	Average of 5 bars	3 before treatment	0·102	0·062	0·013	0·011	
		2 after treatment	0·105	0·053	0·010	0·012	
3	(*a*) N	After treatment	0·12	0·20	0·014	0·009	0·019
	S	After treatment	0·11	0·20	0·010	0·010	0·020
	R	After treatment	0·10	0·13	0·016	0·010	0·017
	(*b*) T	Not treated ..	0·37	0·06	0·01	0·01	—
	U	After treatment	0·38	—	—	—	—

The individual bars of any one class did not vary from the average to any marked extent. It will be seen from these results that the passage of the hydrogen has had no appreciable effect on the chemical composition of the copper, except that a certain amount of hydrogen has been retained by the copper. The amount of hydrogen retained by the copper appears to be small when expressed as a percentage, but when worked out on an atomic basis it is seen to be present to a greater extent on this basis than any of the other impurities in this class of copper. Take bar S for example:—

—	Hydrogen.	Arsenic.	Sulphur.	Copper (by) difference.
Percentage proportions ..	0·02	0·20	0·11	99·65
Atomic proportions	0·02	0·0027	0·0034	1·57
(or	1·00	0·14	0·17	0·78)

It appears probable that the hydrogen is present in solution in the solid copper. A point of interest noticed during the analysis of the different samples of copper was that in the majority of samples of treated copper, even with sulphur as low as 0·03 per cent. to 0·04 per cent., separation of sulphur occurred while dissolving the copper in aqua regia. In the case of the samples of untreated copper analysed, separation of sulphur during solution in aqua regia was only observed in copper containing upwards of 0·31 per cent. of sulphur. This would appear to be due to the collection of the sulphide present in treated copper into globules. (Figs. 6 and 8.)

Tensile Tests.—Only the results obtained on bars of treated copper are given below. Tests made on bars of untreated copper were unsatisfactory, owing to the presence of too many blowholes.

Results of Tensile Tests on Treated Copper.

Class.	Bar.	Percentage of Sulphur.	Percentage of Arsenic.	Breaking Load.	Yield Point.	Elongation. (per cent.)	Reduction in Area. (per cent.)
1	Average ..	0·04	0·6	10·4	5·1	25 (on 2 in.)	20
3	N*	0·12	0·4	12·1	—	33 (on 1·5 in.)	24
4	Electrolytic	—	—	11·1	6 6	17 (on 1·5 in.)	15

* Bar N was the only one of the treated bars of classes 2 and 3 (i.e., with a comparatively high percentage of sulphur) on which a satisfactory tensile test was obtained; all the others broke under a comparatively low load at positions at which segregation had occurred, the fractured surfaces being partly covered by a brownish-black film. This film, it may be added, did not occur on the fractures of any of the untreated bars of Class 2; the untreated bars of Class 3 obtained were too unsound even to make into a test-piece.

Specific Gravity.

Class.	Condition.	Average Specific Gravity.
1	Untreated (all unsound)..	7·58
	Treated (*a*) Unsound*	7·61
	(*b*) Sound	8·70
2	Untreated (all unsound)..	7·48
	Treated	8·77
3	(*a*) Treated	8·71
	(*b*) Untreated (1 bar)	6·65
	Treated (1 bar)	8·68

* This result was obtained by multiplying the observed conductivity of the unsound bar by $\frac{\text{specific gravity of sound copper}}{\text{specific gravity of the unsound bar}}$

These unsound treated bars were obtained by casting directly after passage of the hydrogen. The sound bars were obtained by allowing the copper to solidify in the furnace, remelting and casting.

Electrical Conductivity.—Three bars were tested for electrical conductivity. All three belonged to Class 2 (sulphur, about 0·1 per cent.; arsenic, about 0·06 per cent.). One bar was of copper treated with hydrogen; a second was of untreated copper melted and cast under charcoal, and was the only bar of untreated copper which cast soundly; a third was of copper melted down rapidly in air and cast; it was unsound, with a specific gravity of 7·48. The following results were obtained:—

Effect of Treatment on Electrical Conductivity.

Bar.	(Pure Copper 100).
Treated with hydrogen ...	84
Untreated, melted and cast under charcoal	86
Untreated, melted and cast without charcoal	84

The lowering of the electrical conductivity by the passage of hydrogen is readily explained by an examination of the microstructure of treated and

THE EFFECTS OF HYDROGEN ON COPPER.

FIG. 1. ×150.

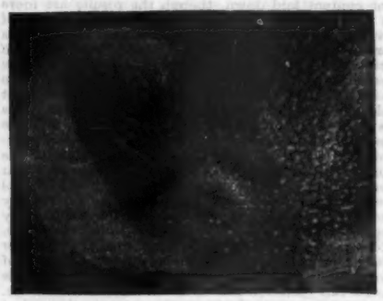


FIG. 2. ×600.

FIG. 3. ×150.

FIG. 4. ×600.

Reduced by one-third.

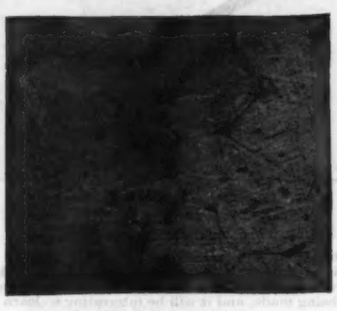


FIG. 5. ×150

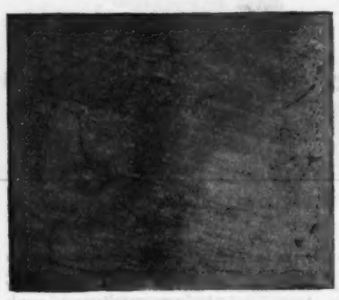


FIG. 6. ×150.

FIG. 7. ×150.

FIG. 8. ×150.

Reduced by one-third.

untreated copper of this class, and will be referred to later.

Examination of Microstructures.—Sections of the screwed ends of the tensile test-pieces were polished and etched with a solution of ferric chloride and hydrochloric acid.

Class 1—*Copper.*—Arsenic, 0·6 per cent.; sulphur, 0·04 per cent.

(*a*) *Untreated.*—Photomicrographs of this copper are shown in Figs. 1 and 2, page 392. They exhibit dark areas of material rich in copper surrounded by cell walls of a material rich in arsenic. The small black spots in the dark area consist of sulphide; these spots were more or less uniformly distributed throughout the copper, being mainly present in the dark areas.

(*b*) *Treated.*—Photomicrographs of this copper are shown in Figs. 3 and 4 on the opposite page. The small area of the photomicrograph is representative of the structure throughout the mass. All the sulphide was contained in the cell walls. The cell walls appeared to be thinner than in the untreated copper. In one or two places a sharp thin black line was observed running down the centre of the cell walls.

Class 2—*Copper.*—Arsenic, about 0·06 per cent.; sulphur, about 0·10 per cent.

(*a*) *Untreated.*—The structure of this copper is shown in Fig. 5, and is seen to consist of crystals of copper bordered by thin black lines. The sulphide spots are dotted over the whole surface of the copper, some appearing in the areas and some at the boundaries of the crystals.

(*b*) *Treated.*—The structure is shown in Fig. 6, page 392. The passage of the hydrogen has caused a concentration of the sulphide at the boundaries of the crystals. No sulphide was observed in the crystal areas. The same tendency to reduce the thickness of the cell wall is observable here also.

Class 3—*Copper.*—(*a*) Arsenic, between 0·13 per cent. and 0·4 per cent.; sulphur, about 0·10 per cent. All treated. The structures of the copper of this class were all similar to the structure shown in Fig. 3. (*b*) Arsenic, about 0·06 per cent.; sulphur, 0·3 per cent. to 0·4 per cent.

1. *Untreated.*—The structure of this copper is shown in Fig. 7, on the opposite page, and is similar to that shown in Fig. 4, except that there is considerably more sulphide present and that a greater proportion of the sulphide appears to be situated at the crystal boundaries. In some parts of the sections examined sulphide spots were grouped roughly in areas with no distinct boundary, thickly dotted spots of sulphide appearing on background of copper.

2. *Treated.*—The structure of this copper is shown in Fig. 8. The passage of the hydrogen is seen to have effected a remarkable change in the structure of the metal. The crystal areas are now quite free from sulphide, which is concentrated in well-defined areas surrounding the crystals of copper. These areas show an eutectic structure consisting of minute spots of sulphide in a matrix of copper.

The main conclusion to be drawn from the micrographic examination of the various classes of treated and untreated copper appears to be that hydrogenised copper is capable of forming an eutectic with cuprous sulphide, and that in consequence all the sulphide in such a copper is concentrated at the borders of the copper crystals.

The concentration of the sulphide at the borders of the copper crystals would explain many of the peculiarities of treated copper described earlier in the paper—*e.g.*, the low conductivity and premature failure under load, of copper containing 0·1 per cent. sulphur.

Summary and Conclusion.—1. Copper treated in the molten state with hydrogen will, under suitable casting conditions, cast sound, while copper which has not been treated with hydrogen but has been deoxidised by carbon will not cast sound under the same conditions of casting. This points to an important difference between the solubilities of hydrogen and carbon monoxide in copper.

2. Copper treated with hydrogen is liable to pipe badly on casting unless a compartively large amount of arsenic is present. In the case of impure copper, the pipe which is formed on casting is lined with well-defined crystals of copper which, however, are absent from the pipe formed in treated electrolytic copper.

3. In the case of treated copper, all the sulphide is concentrated at the borders of the crystals, probably owing to the formation of an eutectic of hydrogenised copper and cuprous sulphide. In untreated copper the sulphide, when not present to an excessive extent, is distributed more or less evenly through the metal.

4. The concentration of the sulphide at the borders of the crystals causes a lowering of the electrical conductivity and a liability for the copper to fail prematurely under load, at least when 0·1 per cent. of sulphur or more is present. The separation of sulphur during the solution of treated copper in *aqua regia* may be due to the same cause.

5. Solid copper is capable of retaining a certain amount of hydrogen permanently in solution.

These results confirm and supplement the work of G. Guillemin and R. Delachanal,* who found hydrogen, carbon monoxide, and carbon dioxide occluded in copper alloys and in tin. In sound castings at least 90 per cent. of the occluded gas was hydrogen. In unsound castings the gas contained a considerable proportion of carbon monoxide and some carbon dioxide. They state that the presence of occluded hydrogen in sound castings had no deleterious effect on the mechanical properties of the metal, and that chill cast bars contained less gas than bars cast in the ordinary manner.

A. Sieverts and W. Krumbhaar† found the solubility of hydrogen in copper to be proportional to the temperature and the square root of the pressure, and to be much greater in the liquid than in the solid state.

APPENDIX.

Methods of carrying out chemical analysis and determination of tensile strength, specific gravity and electrical conductivity.

CHEMICAL ANALYSIS.

Arsenic and Antimony.—The distillation method was finally adopted for the estimation of these impurities, the arsenic being precipitated as sulphide, redissolved in aqua regia; reprecipitated as magnesium-ammonium-arsenate, and after ignition weighed as magnesium pyro-arsenate.

The antimony was precipitated as sulphide and converted into tetroxide by fuming nitric acid. After ignition it was weighed as tetroxide.

Bismuth.—Abel and Field's method was used, the bismuth being precipitated as hydrate and weighed after ignition as trioxide.

Sulphur.—This was estimated by solution of the copper in aqua regia and subsequent precipitation as barium sulphate. In the cases noted in the body of the paper, in which separation of sulphur occurred during solution of the copper in aqua regia, the separated sulphur was filtered off and estimated separately by oxidation with bromine water and subsequent precipitation as above.

Hydrogen.—This was estimated by combustion of filings of copper at 900 deg. C. in pure oxygen, which was finally dried by phosphorus pentoxide before passing over the copper, and the water vapour formed during its passage over the heated copper absorbed by phosphorus pentoxide and weighed directly.

Tensile Tests.—A round bar with a test diameter of ½ in. and a stretching length of 2 in. where possible was used.

Specific Gravity.—This was measured on the whole bar as cast by weighing the bar in air and again in water, and calculating the specific gravity from these results.

Electrical Conductivity.—In order to measure the electrical conductivity a longer and thinner bar than before was cast. The bar was about a foot long and ¼ in. diameter, and was cast on end, with a small cup-shaped reservoir (holding about 100 grammes of metal) at the top to supply molten metal during solidification. The sound bar so obtained was then milled down to ¼ in. square and the electrical conductivity measured by taking the drop in potential along a measured length of the bar in a Kelvin double-bridge apparatus. During milling the bar of treated copper appeared to be distinctly softer and worked more freely than the other two.

The experiments were carried out in the Metallurgical Laboratories of the Municipal College of Technology, Manchester.

THE REMOVAL OF INTERNAL STRESS IN 70:30 BRASS BY LOW TEMPERATURE ANNEALING.†‡

By H. MOORE, O.B.E., B.Sc., F.I.C., and S. BECKINSALE, B.Sc., A.I.C.

IN the 1914 May Lecture to this Institute, Heyn§ indicated the dangers arising from the presence of internal stress in metals, and referred to the removal of such stress by heating to comparatively low temperatures. Merica and Woodward‖ in several important papers have discussed the season cracking of brass and its causation by initial stress, and have stated that the stresses may be almost entirely removed by annealing at temperatures of 300 deg. to 400 deg. C., without sensible effect on the ordinary physical properties. Season cracking has been discussed by Campbell,¶ Bassett** and Webster,†† and by Price‡‡, who found that internal stress was removed from cartridge cases by heat treatment for 1 hour at 260 deg. C. Rawdon* investigated very thoroughly the use of mercury solutions for the detection of internal stress which may result in season cracking in brass. Solutions of mercury salts have been used for this purpose by other workers named above. The authors are pleased to note that F. Rogers† has recently referred to his introduction and development of this method of testing, in 1905, at the Research Department, Woolwich, where the test has since been extensively used. Hatfield and Thirkell‡ have studied internal stress and season cracking in articles spun from brass sheet, and the development of stress by spinning.

Charpy,§ Bengough and Hudson,‖ and Mathewson and Phillips,¶ have observed the slight hardening occurring when cold-worked brass is first heated to temperatures not exceeding 300 deg. C. This phenomenon has been discussed by Carpenter and Taverner.**

It is now generally recognised that considerable internal stresses frequently exist in brass articles which are subjected to cold-work operations during manufacture, and that these stresses may bring about failure by cracking, either through lapse of time or under the action of certain substances, among which mercury (in the form of solutions of its salts) and ammonia are peculiarly active. For some time the authors have employed the term "stress cracking" to indicate this type of failure, and "accelerating agents" to indicate those substances which hasten the development of cracks in brass in a state of stress.

Internal stresses are readily removed by annealing. The Brinell hardness of fully-annealed 70:30 brass is in the neighbourhood of 50 to 60, and may be raised by cold-working to about 210. Any desired intermediate degree of hardness may be obtained by controlling the amount of deformation imparted in the cold-working operation. Annealing, as usually understood and applied, removes the increased hardness due to cold work to a large extent, if not entirely. It is frequently important, however, to retain the increased strength imparted by cold work, and brass articles made, for example, by drawing, frequently require a Brinell hardness of 100 to 160 to ensure serviceability. These considerations indicate that an annealing which seriously reduces the hardness of the brass is not generally applicable.

It is possible in many cases to lay down limits of Brinell hardness within which the best results are obtained in service. These limits are not necessarily the same for different parts of the same article; it is frequently desirable that the article should be harder in one region than in another, and systematic variations from, say, 80 to 160 Brinell hardness may give the best results. It is therefore useful to know the effect of any given treatment on brass of any hardness.

In the course of an investigation into the failure by stress-cracking of certain components of war stores made from 70:30 brass by a process of cold working, it was found that internal stress could be entirely removed without important reduction of hardness, by annealing within certain limits of temperature. This led to the more careful determination of the minimum temperature at which internal stress can be completely removed and the effect of annealing, within the temperature range studied, on Brinell hardness. Both as regards the removal of stress and the effect on hardness, length of time of annealing is a factor of great importance. The results, which should be of perfectly general application to cold-worked 70:30 brass, are given in this communication. The experimental work described has formed part of a general investigation into internal stress and stress cracking in brass which has been in progress in the Research Department, Woolwich, for some time; it is hoped to publish results dealing with other aspects of the problem at later dates.

A considerable amount of evidence has accumulated, indicating that (1) a cold-worked article of 70:30 brass in which internal stress is present involving any risk of cracking, sooner or later, will invariably crack in a short time when acted upon by mercurous nitrate solution of suitable strength; (2) specimens free from serious internal stress do not crack after being submitted to the action of mercurous nitrate solution. Such a solution may therefore be used as a test for the presence of internal stress.

For the purposes of this work it was necessary to prepare large numbers of specimens in a state of internal stress and identical in their properties. Small flanged cups spun from fully annealed 70:30 brass sheet were found to be entirely suitable. Great numbers of these (not annealed) have been tested in mercurous nitrate

* *Comptes Rendus*, November, 1910; Journal of the Institute of Metals, vol. iv.

* *Berichte der deutschen chemischen Gesellschaft*, 1910, vol. xliii, pages 893 to 900; Journal of the Institute of Metals, vol iii, page 288.

† Paper read before the Institute of Metals, March 12, 1920.

‡ Communication from the Research Department, Woolwich.

§ E. Heyn, "Internal Strains in Cold-Wrought Metals and some Troubles caused thereby," Journal of the Institute of Metals, No. 2, 1914, vol. xii, page 3.

‖ P. D. Merica and R. W. Woodward, "The Failure of Structural Brasses," Transactions of the American Institute of Metals, 1915, vol. ix, page 298. "Initial Stress and Corrosion Cracking," Proceedings of the American Society for Testing Materials, 1918, vol. xviii, Part II, page 165. "Failure of Brass," Bureau of Standards Technologic Paper, No. 82, 1917.

¶ W. Campbell, "Season Cracking and Splitting of Condenser Tubes and Pipes," Proceedings of the American Society for Testing Materials, 1918, vol. xviii, Part II, page 147.

** W. H. Bassett, "The Causes and Prevention of Corrosion Cracking," Proceedings of the American Society for Testing Materials, 1918, vol. xviii, Part II, Page 153.

†† W. R. Webster, "Season Cracking," Proceedings of the American Society for Testing Materials, 1918, vol. xviii, Part II, page 163.

‡‡ W. B. Price, "The Prevention of Season and Corrosion Cracking of Brass Artillery Cases by Special Heat Treatment," Proceedings of the American Society for Testing Materials, 1918, vol. xviii, Part II, page 179.

* H. S. Rawdon, "The Use of Mercury Solutions for Predicting Season Cracking in Brass," Proceedings of the American Society for Testing Materials, 1918, vol. xviii, Part II, page 189.

† Journal of the Institute of Metals, No. 2, 1919, vol. xxii, page 114.

‡ W. H. Hatfield and G. L. Thirkell, "Season Cracking," Journal of the Institute of Metals, No. 2, 1919, vol. xxii, page 67. (A useful bibliography is appended to this paper.)

§ G. Charpy, "Recherches sur les alliages de cuivre et de zinc," *Contribution à L'Etude des Alliages*, 1901, page 1.

‖ G. D. Bengough and O. F. Hudson, "The Heat Treatment of Brass," Journal of the Institute of Metals, No. 2, 1910, vol. iv, page 92.

¶ C. H. Mathewson and A. Phillips, "Recrystallisation of Cold-Worked Alpha Brass on Annealing," Transactions of the American Institute of Mining Engineers, 1916, vol. liv, page 608.

** H. C. H. Carpenter and L. Taverner, "The Effects of Heat at Various Temperatures on the Rate of Softening of Cold-Rolled Aluminium Sheet," Journal of the Institute of Metals, No. 2, 1917, vol. xviii, page 115.

solution at short and long intervals after spinning, and without exception have developed numerous cracks, generally similar in form, number, and in the time required for their development. The composition of the brass sheet, which was 0·035 in. thick and had a Brinell hardness of 58, was as follows :—

	Per Cent.
Copper	70·4
Zinc (by difference)	29·5
Tin	<0·01
Iron	0·04
Lead	<0·01
Nickel	0·04
Bismuth	0·0006
Manganese	0·001
Antimony	0·004
Arsenic	Nil

The form and dimensions of the spun cups are shown in Figs. 1 and 2; they were spun, from discs 4·2 in. in diameter, on a former by means of a roller, the flanges being turned over afterwards. The cups were not annealed during any of the spinning operations. Brinell hardness tests made on the exterior surfaces of spun cups, along a diameter with a ball of 1 mm. diameter and a load of 10 kg., gave the following average results :—

	Brinell Hardness Number.
On flange	143
Junction of flange and dome	148
0·25 in. from flange	142
0·5 in. from flange	125
0·75 in. from flange	112
1·0 in. from flange	83
1·25 in. from flange	64
1·5 in. from flange	62
1·75 in. from flange	62
2·0 in. from flange	62

At each position tested the variations from the average Brinell hardness figures given were very small.

The mercurous nitrate test is carried out as follows. The article or specimen to be treated is pickled for 30 seconds in a bath containing 40 volumes of nitric acid (1·42 specific gravity) and 60 volumes of water. It is then thoroughly washed in water and immersed for 5 minutes in a 1 per cent. solution of mercurous

Fig. 1.

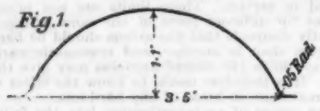
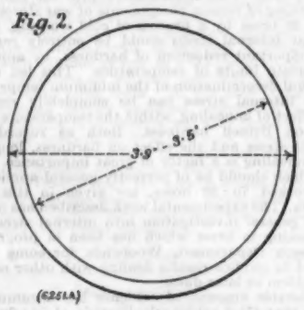


Fig. 2.



(6251A)

nitrate containing 1 per cent. by volume of nitric acid (1·42 specific gravity). The surface becomes well coated with mercury. The specimen is kept under observation during and after this treatment, and the time at which cracks first appear is noted. Cups which have been kept at ordinary temperatures after spinning crack within 3 minutes from time of immersion in mercurous nitrate solution. The cracks commence at the junction of the flange and dome and extend in a direction at right angles to the flange. Small subsidiary cracks branching from the main cracks and parallel to the flange develop later. Figs. 3 and 4, page 395, show the form of the cracks. Their extent and nature and the time in which they appear give a good indication of the distribution and relative amount of stress present. When stress has been almost completely removed by annealing, extremely fine cracks develop in the dome many days after the mercurous nitrate test, but no cup has yet been found to crack at a longer interval than 28 days after immersion. Mercury-treated cups which do not crack after prolonged storage are regarded as being free from harmful internal stresses.

The effect of the heat treatments applied on Brinell hardness was determined, not on the cups themselves but on flat strips of brass (of similar composition and made from the same materials) cold-rolled to different degrees of hardness. The cups were not suitable for the hardness tests since the hardness varied considerably at different points in the same cup, and also because it was desired to ascertain the effect of the treatment on brass of several widely different degrees of initial hardness. The strips were not given any heat treatment after rolling and before the experimental low-temperature annealing under investigation. Strips of Brinell hardness of about 90, 120, 165, and 200 were used. Although there were appreciable variations in hardness between different strips of the same batch, each specimen was very uniform in hardness.

The results of tensile tests made on this material and on fully-annealed sheet are given below to give a general indication of the tensile strengths corresponding to the various Brinell hardnesses mentioned in the course of this paper.

TABLE I.

Mark.	Brinell Hardness.	Maximum Load.	Elongation per Cent. on $4\sqrt{\text{area}}$.
		tons per sq in.	
A	196	52·0	7
	196	51·6	7
B	149	39·7	15
	147	38·6	14
C	119	28·3	31
	117	28·4	11 (broke near end).
D	92	25·3	54
	91	24·9	53
Annealed sheet	58	19·7	60

The Brinell hardness tests were made with a ball of 2 mm. diameter and a load of 40 kg.; each result given is the average of at least three tests. The accuracy of hardness determination is considered to be well within 2 per cent., and usually within 1 per cent. The advantages of the Brinell test for work of this kind are very considerable, especially when a small ball, with corresponding small load, is used. The test does not involve destruction of the specimen, and the same specimen can be tested before and after treatment, and also at successive stages in the treatment. Several tests can be made on the same piece at each stage, for checking purposes, and such tests afford a useful indication of the degree of uniformity of the material used.

The procedure followed was to anneal, for different periods, strips of known hardness and spun cups at temperatures ranging from 100 deg. C. to 325 deg. C., to submit the cups to the mercurous nitrate test and to determine the hardness of each strip before and after annealing. Fresh cups, in no case fewer than three in number, were used for each temperature and time of annealing, and at the more critical temperatures and times eight to twelve cups were treated.

Annealing at 100 deg. C. was carried out in a steam oven. Protracted annealing at 200 deg. C. was conducted in a closed chamber surrounded by molten carnauba wax. All other annealings, including those for less than 24 hours at 200 deg. C., were carried out in a bath of molten carnauba wax, the temperatures being taken with a standardised mercury thermometer. The wax was thoroughly and constantly stirred by means of a paddle, and the specimens were supported on a wire mesh tray 1·5 in. above the bottom of the bath, which was heated by a gas ring. In the steam oven and wax bath the temperature was maintained within ± 1 deg. or 2 deg. C. of that desired, but rather greater variations occurred in the long heatings at 200 deg. C., although the temperature never rose above 203 deg. C. All cups were thoroughly examined for cracks before and after annealing; no cracks were found. The detailed results of the experiments are given in Table II.

TABLE II.

Temperature.	Time in Annealing Bath.	Time in which Cups Cracked after Treatment in Mercurious Nitrate Solution.	Brinell Hardness Numbers of Brass Strips submitted to the same Annealing Treatment.							
			Series A.		Series B.		Series C.		Series D.	
			Before Annealing.	After Annealing.	Before Annealing.	After Annealing.	Before Annealing.	After Annealing.	Before Annealing.	After Annealing.
deg. C.										
100	4 days ..	Cracked in solution	209	213	166	171	125	129	93	98
	11 days ..	Cracked in solution	209	213	166	169	125	123	93	92
	32 days ..	Cracked in solution	209	216	166	167	125	122	93	92
	55 days ..	Cracked in solution	212	201	169	161	125	129	93	92
200	1 minute	Cracked in solution	202	196	158	160	124	123	94	95
	5 minutes	Cracked in solution	201	199	162	164	124	124	90	91
	10 minutes	Cracked in solution	192	200	157	164	119	123	91	92
	20 minutes	Cracked in solution	188	210	158	161	130	132	90	91
	1 hour ..	Cracked in solution	209	221	169	177	125	137	93	94
	2 hours ..	Cracked in solution	211	227	168	183	126	131	91	91
	3 hours ..	Cracked in solution	211	228	169	180	131	137	93	96
	6 hours ..	Cracked in less than 1 hour ..	210	228	166	177	124	127	96	95
	24 hours ..	Cracked in less than 1 hour ..	190	200	154	164	126	126	91	90
	48 hours ..	Cracked in less than 4½ hours ..	189	179	156	157	125	125	98	97
	72 hours ..	Cracked in less than 20 hours ..	186	190	156	165	124	129	90	90
	96 hours ..	Uncracked after 20 days ..	184	174	154	160	124	125	93	90
	120 hours ..	Uncracked after 20 days ..	—	—	—	—	—	—	—	—
225	1 minute	Cracked in solution	—	—	—	—	—	—	—	—
	5 minutes	Cracked in less than 3 hours ..	—	—	—	—	—	—	—	—
	10 minutes	Cracked in less than 24 hours ..	—	—	—	—	—	—	—	—
	20 minutes	Cracked in less than 24 hours ..	—	—	—	—	—	—	—	—
	1 hour ..	Cracked in solution	210	227	171	175	125	132	93	91
	2 hours ..	Cracked in less than 20 hours ..	205	219	168	172	123	128	95	95
	3 hours ..	Cracked in solution	207	217	166	175	124	128	93	92
	6 hours ..	5 cups cracked within 24 hours 3 uncracked after 28 days	207	214	165	174	124	129	93	93
	24 hours ..	1 cup cracked within 10 days 2 cups uncracked after 10 days	—	—	—	—	—	—	—	—
	48 hours ..	Uncracked after 10 days ..	—	—	—	—	—	—	—	—
250	1 minute	Cracked in solution	195	208	160	165	113	124	86	92
	5 minutes	Cracked in less than 3 hours ..	196	206	157	166	118	124	89	95
	10 minutes	Cracked in less than 24 hours ..	188	196	156	166	117	127	91	96
	20 minutes	Cracked in less than 24 hours ..	190	195	158	164	115	123	85	95
	1 hour ..	Cracked in less than 24 hours ..	207	207	167	176	121	126	94	94
	2 hours ..	Cracked in less than 10 days ..	206	177	167	175	122	123	90	89
	3 hours ..	Cracked in less than 3 days ..	207	171	165	172	122	123	93	93
	4 hours ..	2 cups cracked after 4 days 1 cup uncracked after 14 days	—	—	—	—	—	—	—	—
	5 hours ..	Uncracked after 14 days ..	—	—	—	—	—	—	—	—
	6 hours ..	Uncracked after 27 days ..	208	154	166	166	126	124	90	92
275	15 seconds	.. ..	194	202	—	—	—	—	—	—
	30 seconds	.. ..	197	212	—	—	—	—	—	—
	45 seconds	.. ..	190	201	—	—	—	—	—	—
	1 minute	Cracked in solution	190	197	156	158	121	124	93	93
	5 minutes	Cracked in less than 24 hours ..	194	192	156	154	121	122	91	89
	10 minutes	Cracked in less than 24 hours ..	192	190	157	163	122	123	95	94
	15 minutes	2 cups cracked in less than 3 days 2 cups uncracked after 14 days	—	—	—	—	—	—	—	—
	20 minutes	4 cups cracked in less than 3 days 4 cups uncracked after 28 days	191	158	156	156	124	122	88	85
	1 hour ..	Uncracked after 28 days ..	209	157	172	170	123	125	94	92
	2 hours ..	Uncracked after 28 days ..	210	148	171	154	127	127	95	91
	3 hours ..	Uncracked after 28 days ..	206	144	172	147	123	122	92	90
	6 hours ..	Uncracked after 28 days ..	208	138	173	132	124	119	94	89
280	15 minutes	Uncracked after 14 days ..	—	—	—	—	—	—	—	—
	20 minutes	Uncracked after 14 days ..	—	—	—	—	—	—	—	—
	60 minutes	Uncracked after 14 days ..	—	—	—	—	—	—	—	—
285	20 minutes	Uncracked after 14 days ..	—	—	—	—	—	—	—	—
	60 minutes	Uncracked after 28 days ..	—	—	—	—	—	—	—	—
290	20 minutes	Uncracked after 14 days ..	—	—	—	—	—	—	—	—
300	1 minute	Cracked in less than 3 hours ..	186	199	156	164	126	126	90	92
	5 minutes	.. ..	192	161	158	157	123	120	93	91
	10 minutes	Uncracked after 28 days ..	194	148	155	155	122	121	95	93
	15 minutes	1 cup cracked after 8 days 2 cups uncracked after 20 days	214	154	169	160	125	128	93	91
	20 minutes	Uncracked after 14 days ..	193	137	154	136	123	118	92	90
	30 minutes	Uncracked after 28 days ..	211	144	167	146	127	128	93	94
325	1 minute	Cracked in less than 3 hours ..	—	—	—	—	—	—	—	—
	5 minutes	Uncracked after 28 days ..	—	—	—	—	—	—	—	—
	10 minutes	Uncracked after 28 days ..	—	—	—	—	—	—	—	—
	20 minutes	Uncracked after 28 days ..	—	—	—	—	—	—	—	—

SUMMARY AND CONCLUSIONS.

In these experiments the minimum times in which internal stress was completely removed by low-temperature annealing were :—

Temperature. Deg. C.	Time.
200	96 hours
225	48 hours
250	5 hours
275	1 hour
300	20 minutes
325	5 minutes

The minimum times in which any notable softening effect was produced were :—

Temperature Deg. C.	Approximate Initial Brinell Hardness. 200	165	120	90
200	No			
225		Important		
250	2 hours		Reduction	
275	20 minutes	2 hours	in	
300	5 minutes	20 minutes		Hardness

From these two tables it will be seen that : (1) The harder the brass, the lower the temperature and the shorter the time of annealing, which will cause a reduction of hardness.

2) 70 : 30 brass cold-worked to about the maximum possible hardness (about 200) begins to show some reduction of hardness at temperatures and times which are insufficient to remove internal stress completely. This degree of hardness is, however, rarely obtained in brass articles, and is probably never necessary. Even in brass of this hardness internal stress may be completely removed by treatment involving only a very moderate reduction of hardness.

(3) For 70 : 30 brass cold-worked to a Brinell hardness not exceeding 165, there is a useful range of temperature, in which internal stress may be completely removed without appreciable loss of hardness. Annealing for 1 hour at 275 deg. C., or for rather shorter times at slightly higher temperatures, is a treatment which is generally suitable. In cases in which there is no serious objection to protracted annealing slightly lower temperatures may be used, and these involve less risk of undesirable softening. Five hours at 250 deg. C. might be suitable in such cases. It is rarely, if ever, that a Brinell hardness exceeding 165 is required in 70 : 30 brass, and lower figures are sufficiently high for most purposes.

The behaviour, under a variety of tests, of spun cups such as have been used in this work, indicates that when no heat treatment has been applied after spinning the internal stresses are very high. It is probably a safe assumption that they are at least as high as the stresses present in any article made by cold-working 70 : 30 brass. The authors conclude, from their experience with spun cups and with numerous manufactured articles of various forms, that a treatment which will remove the stresses existing in the spun cups described is sufficient to remove the internal stresses from any manufactured article.

Treatments which do not entirely remove internal stresses may nevertheless be sufficient to bring about a great reduction in such stresses. In the spun cups the reduction of stress is indicated by the longer time required to develop cracks after mercury treatment, and by the diminution in number, length, and width of the cracks.

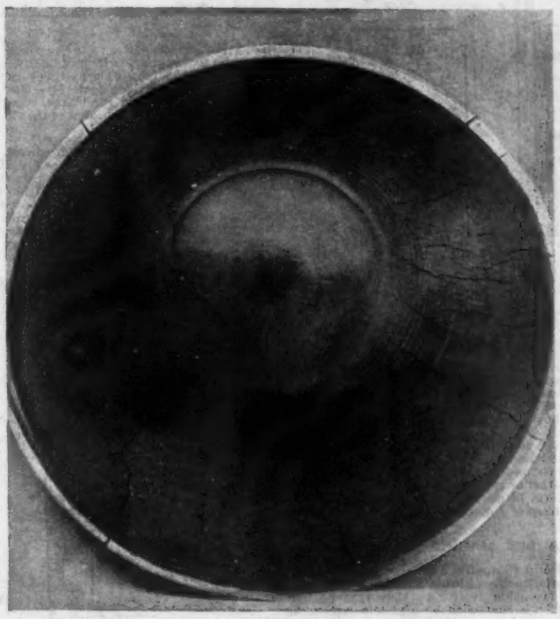


FIG. 3.

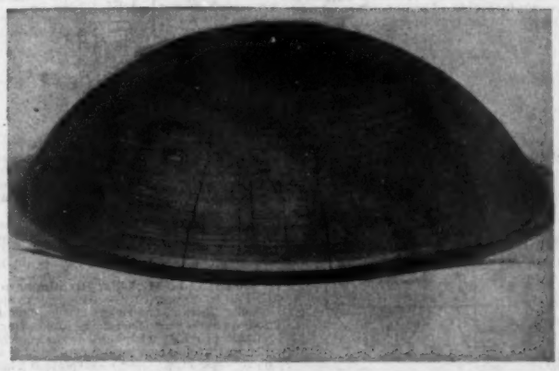


FIG. 4.

View of Cups (outside surfaces) spun from 70 : 30 brass and treated with mercurous nitrate solution, showing cracks. Actual size.

Internal stress is not removed, and does not appear to be appreciably reduced, by annealing at 100 deg. C. for many weeks.

The first effect of low-temperature annealing is a distinct increase of hardness. This hardening has been observed at all temperatures used between 100 deg. C. and 300 deg. C. The higher the temperature the shorter is the duration of this increased hardness.

The authors are indebted to Mr. D. H. Walters, B.Sc., A.I.C., for much assistance in the experimental work.

THE DANISH NAVY.—The Danish journals announce the retirement of Mr. Jean Charles Tuxen, who has been Director of Naval Construction and Machinery, Royal Danish Navy, for a period of twenty-five years. It is interesting to note that in 1874 Mr. Tuxen entered the Royal Naval College, Greenwich, and that in 1877 he was first in the final examination. Director Tuxen has many friends in this country and has for many years been a member of the Institution of Naval Architects.

CATALOGUES.

Oil Power.—A little monthly publication issued by Messrs. Plenty and Son, Limited, Newbury, gives useful information about oil fuel for engines, boilers, &c.

Steel Piling.—Two issues of a monthly publication, published by the British Steel Piling Company, Dock House, Billiter-street, London, E.C. 3, contain some interesting information about pile-driving hammers and general plant.

Miner's Compass.—A dipping needle, or "miner's compass," for tracing the presence of magnetic iron ore and measuring magnetic deviation or inclination, shown in a very neat and compact leather case, is illustrated in a leaflet to hand from Messrs. T. Cooke and Sons, Limited, 3, Broadway, Westminster, London, S.W. 1.

Concrete Inserts.—A catalogue of bolt hanger sockets and slotted insert pieces comes from Building Products, Limited, 44, King's-road, London, S.W. 3. These inserts are for placing in concrete walls, floors, ceilings, &c., during the laying of the concrete so that shafting, hangers, &c., can afterwards be fixed without cutting the hard concrete.

Non-Ferrous Castings.—A catalogue from Haywood Foundries, Limited, of 30, Seaton-street, Euston-road, London, N.W. 1, shows some micro-photographs of their metals. Castings are made at these foundries in brass, copper, aluminium, anti-friction metals and various bronzes, including high tensile qualities for steam fittings, gear wheels, propellers and chemical manufacturing plant.

Steel Sheet Piling.—Full size drawings of the sections of steel sheet piling made by the Cargo Fleet Iron Company, Limited, of Middlesbrough, to the designs of the Lackawanna Steel Company, have reached us. The straight sheet piling is 12½ in. between the locking centres and has a web ½ in. thick—the weight being 40 lb. per foot run of piling bar or 38 lb. per square foot of surface. The circular piling, with ½-in. web, weighs 3 lb. less per square foot of surface. In this type the web is arched in cross-section.

Wet Air Filters.—The method of sending cool, clean and moist air through an electric generator, and the advantages of so doing, are lucidly explained in a catalogue issued by the Premier Cooler and Engineering Company, Limited, of Shalford, near Guildford. The filters are made in 25 standard sizes, with capacities ranging from 2,700 cub. ft. to 63,000 cub. ft. of air per minute. The air is washed by water spray, filtered, and all free moisture removed during its passage through the machine. The system is also applicable to general purification of the atmosphere in factories and other buildings.

Saws.—Messrs. E. C. Atkins and Co., Indianapolis, U.S.A., claim to make the greatest variety of saws of any firm in the world, and it will not be easy to dispute the claim. Their catalogue extends to 260 pages well filled with lists and illustrations of saws for wood, metal, cork, ice, bone and everything that can be sawn by hand or machine. Wood cutting seems to call for a great variety of tooth form, while metal of all kinds, and at all cutting speeds, needs very little variation of tooth. The firm also make a great variety of knives for machines, as well as trowels and other hand tools made of similar material to saw blades. Sharpening, setting, swaging, and other tools for dressing saws are dealt with in the catalogue, which is really a very remarkable and most instructive book.

Traction Engines.—Steam traction engines are well represented in a catalogue received from Messrs. Marshall, Sons and Co., Limited, of Gainsborough, who make four sizes with single cylinders and four sizes with compound cylinders. The four sizes of single-cylinder engines will handle loads of 12 tons, 15 tons, 18 tons and 20 tons, respectively, on fair roads and moderate inclines at a speed of 4 m.p.h., or up inclines of 1 in 12 at 2 m.p.h. The economical brake horse-powers for belt driving corresponding to these hauling powers are 18, 21, 24 and 28. The compound sets are only slightly more powerful, and are chiefly recommended for use where water is scarce. These traction engines maintain their position in their own spheres of work irrespective of the intrusion of tractors, lorries, &c. They are hauling engines of slow speed and great power, taking, for example, four large wagons of flour, or two large wagons of broken stone, with a sleeping van for the men. All the latest improvements of material and workmanship in engines and boilers are embodied in them, and they form a very considerable item of our exports.

WORLD'S PRODUCTION OF PETROLEUM.—The following figures of the world's production of petroleum, taken from *Power*, New York, are interesting. The total world production in 1918 was 514,729,354 barrels of 42 gallons, equal to 69,975,036 metric tons, of which the United States produced 69·15 per cent., Mexico 12·40 per cent., Russia 7·86 per cent., Dutch East Indies 2·58 per cent., Roumania 1·70 per cent., India 1·55 per cent., Persia 1·40 per cent., and Galicia 1·09 per cent. The total production from 1857 to 1918 was 7,503,147,138 barrels of 42 gallons, equal to 1,006,398,791 metric tons, of which total the United States produced 61·42 per cent., Mexico 3·90 per cent., Russia 24·95 per cent., Dutch East Indies 2·51 per cent., Roumania 2·02 per cent., India 1·41 per cent., Persia 0·19 per cent., Galicia 2·05 per cent., Peru 0·33 per cent., Japan and Formosa 0·51 per cent., Trinidad 0·10 per cent., Egypt 0·07 per cent., Argentina 0·06 per cent., Germany 0·22 per cent., Canada 0·33 per cent., and other countries 0·02 per cent.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Name, &c., of the Communicators are given in italics.

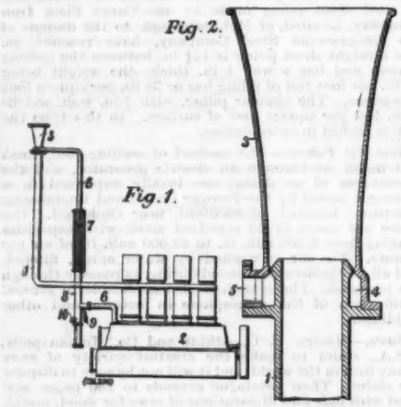
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

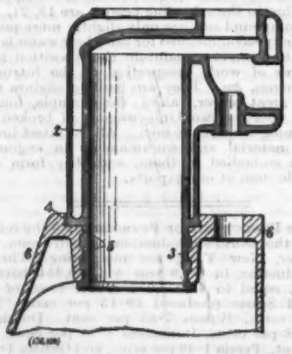
GAS ENGINES, PRODUCERS, HOLDERS, &c.

136,206. W. Hill, Chesterton, J. A. Cork, Chesterton, and The National Gas Engine Company, Limited, Ashton-under-Lyne. Crank-Cases. (4 *Figs.*) October 7, 1918.—The invention relates to the ventilation of the crank cases of internal combustion engines, and it consists in using the exhaust gases from the engine to suck out gases or vapours from the crank-case. Fitted on to the exit of the exhaust pipe 1 of an internal-combustion engine 2 is a trumpet-shaped mouthpiece 3. The base of this mouthpiece is so formed with respect to the end of the exhaust pipe 1 as to constitute an annular space 4, having an opening 5 with connecting means for a pipe 6 leading from the crank-case of the engine 2. The exhaust gases proceeding from the pipe 1, on emerging through the mouthpiece 3, cause a



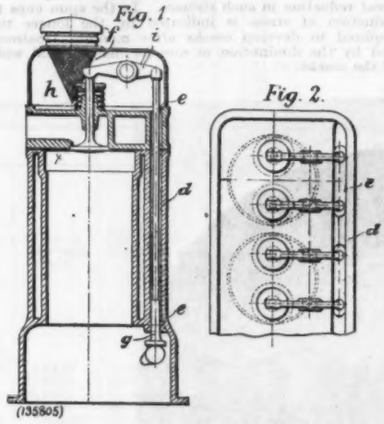
reduced pressure therein, which serves to create a partial vacuum in the annular space 4, whereby the gases or vapours are sucked from the crank-case through the pipe 6. Interposed in the pipe 6 is a condenser 7 for cooling the gases or vapours as they are drawn from the crank-case. Below the condenser is a separator consisting of a straight length of pipe 8, of larger diameter than the pipe 6. The condensed gases or vapours collect in the lower part of this pipe and may be drawn off through a valve 9, the separated water being automatically discharged by an outlet 10, leading from the bottom of the pipe 8. The portion of the pipe 6 connecting the crank-case to the separator enters (the latter at point above the water discharge pipe 10. (*Accepted December* 4, 1919.)

136,108. S. S. Guy, Compton, near Wolverhampton Internal-Combustion Engines. (1 *Fig.*) June 6, 1919.—According to this invention, the upper half of the crank-case 6 is cast on to the cylinder or cylinders 2, the latter being placed in the mould for that purpose prior to the casting operation. By this means the rigidity and other favourable features of the unit construction are secured in conjunction with a choice of



different materials for the two parts. The cylinder 2 is provided with an extension 3 at the base, and with an outwardly-inclined flange 4. In order to afford an intimate and firm connection with the crank-case to be cast on to it, the said flange and extension may be rough machined, and for the same purpose the latter may be also formed with a series of annular grooves 5 or other projecting portions. (*Accepted December* 17, 1919.)

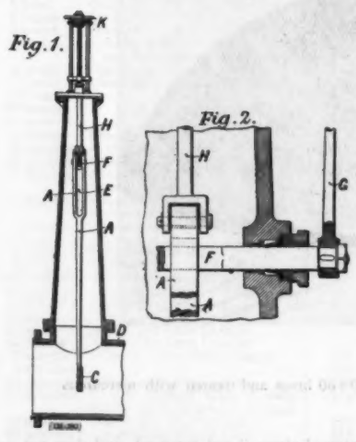
135,805. Crossley Motors, Limited, Gorton, Manchester, and R. H. Rose, Gorton, Manchester. Internal-Combustion Engines. (2 *Figs.*) July 18, 1919.—This invention relates to internal-combustion engines of the class in which the lubrication of the overhead valve arrangement is effected by means of conduits, leading from a trough on the upper side through the conduit into the crank chamber. The improvements are characterised by the formation and use of a particular construction of lubricating slot in the outer wall of the crank-case, such slot being covered by a false wall and serving not only as an oil passage, but also to house a valve actuating gear. *d* is a wall running the whole length of the cylinder block and head. This wall may be cast integrally with the cylinder or crank-case, or both, or it may be a separate part attached to faces suitably formed and placed to receive it. The wall *d* is fixed at such a distance from the outer side of the water jacket as to form a narrow



slot *e* having the water jacket wall for its inner side, and at the bottom being open to the crank-case by means of apertures formed between the bases which carry the valve tappet guides *g*, while at the top the slot is open to the chamber A containing the valve rocking lever *i*. The oil filler *f* may be placed in any convenient position above the slot *e*. The oil supplied to the lubricating chamber A is conducted through the slot *e* into the crank-case and the oil vapour and globules are forced upward through the slot *e* by the fluid pressure in the crank-case arising from leakages past the pistons or through other cause. Further the slot *e* acts as a breather or vent to conduct oil to or from the crank-case from any form of mechanical lubrication employed for the valve gear. (*Accepted December* 10, 1919.)

HYDRAULIC MACHINERY.

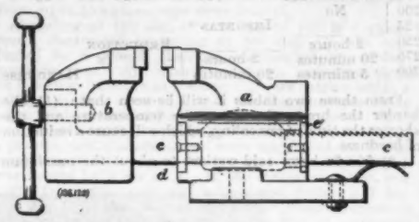
136,080. Glenfield and Kennedy, Limited, Kilmarnock, and E. B. Ball, Kilmarnock. Sluice Valves. (3 *Figs.*) April 24, 1919.—The invention relates to that type of self-closing sluice valve which is controlled by a paddle exposed to the flow of water, and operating to cause closure of the valve by increased velocity of flow due to a burst in the main. According to the invention, the arm A carrying the paddle C is so mounted upon the shaft which it operates to control the valve that it, the arm, may be drawn upwards into a closed chamber formed for it, thus carrying the paddle clear of the bore of the main D, so that



free passage is afforded for brushing or other apparatus. A vertical slot E is formed in the upper end of the paddle arm A, and embraces a shaft F which is of substantially square section, and which is operated by the paddle arm to effect through a lever G the closure of the sluice valve (not shown). Connected to the upper end of the paddle arm is a screwed spindle H, which passes out through the casing B, and is there provided with a hand-operating wheel K. When the spindle H is raised, the slotted portion E of the paddle arm rides over the shaft F and withdraws the paddle C from its working position in the main, into which brushing or like apparatus may then be inserted without obstruction. (*Accepted December* 17, 1919.)

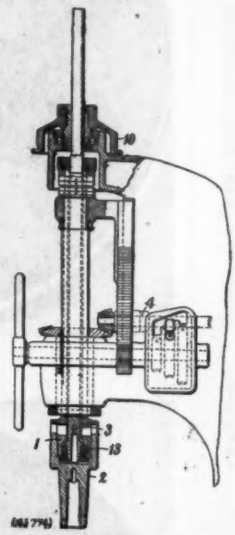
MACHINE AND OTHER TOOLS, SHAFTING, &c.

136,120. W. S. A. Backhouse, Cheadle, Hulme. Bench Vices. (5 *Figs.*) July 12, 1919.—According to the invention, the bar *c* carrying the movable jaw *b*, instead of sliding in direct contact with cast-iron, is mounted to slide in mild steel or like plates *d*, *e*, accurately made and fixed to the front and rear faces of the stationary body part *a* of the vice, the opening in the cast-iron being made somewhat larger than the bar, so as to allow of its being formed (cast) without reference to the accurate fitting of the bar. The plate *d* on the front side is made with an opening corresponding in size and shape to the bar, but the plate *e*, on the rear side, is made with an opening equal in width to, but slightly deeper than, the bar. Further, the top edge of the opening in this plate is bevelled to engage the teeth in the bar. The plates are preferably held at the correct height by lying in grooves milled in the casting, screw holes and screws being provided



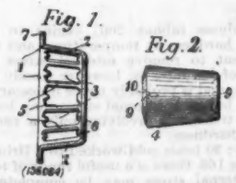
for attaching the plates to the castings. In the case of a round bar, the bar is grooved longitudinally, and pins extending from the plate on the front of the casting engage the grooves to prevent the bar rotating. Alternatively, the bar may have flanges and engage grooves in the plates, those in the rear plate being deeper than the flanges to allow of the tilting of the bar. (*Accepted December* 17, 1919.)

135,774. T. Lumsden, Gateshead. Drilling Machines. (1 *Fig.*) May 22, 1919.—This invention relates to vertical drilling machines, of the kind wherein two co-axial tool spindles are provided arranged the one within the other, said spindles being either simultaneously or independently driven. A vertical drilling or boring machine, in accordance with this invention, comprises two co-axial tool spindles arranged the one within the other, characterised in that the inner or auxiliary spindle is supported by ball bearings carried by the outer or main spindle.



The main spindle 1 is hollow and is provided with a detachable nose 2 adapted to receive a drill. Within the main spindle is an auxiliary spindle 3 also adapted to receive a drill. The main spindle is driven from the shaft 4. The auxiliary spindle 3 is driven by a belt through the pulley 10. The lower end of the auxiliary spindle is supported in the main spindle by a ball bearing 13 which prevents endwise movement of the auxiliary spindle in respect of the main spindle. The feed is common to both spindles. (*Accepted December* 10, 1919.)

136,084. L. M. Ellis, Birmingham. Roller Bearings. (7 *Figs.*) May 2, 1919.—According to the present invention, in a roller bearing, the rollers are confined in a cage comprising a body pressed from sheet metal and having a conical or cylindrical portion provided with holes at the ends of which are oppositely-disposed projections forming spigots for the rollers. 1 is a cage body pressed from sheet metal plate and having a conical portion 2 provided with a series of holes 3 for accommodating the rollers 4, there being ribs or connecting pieces 5 between each two such holes. At the centre of each end of each hole is provided a projection 6 which is integral with the plate. The cage body is completed by an outwardly extending flange 7 at its larger end,



and an inwardly-extending flange at its smaller end. The rollers are provided with recesses 9 at the centre of each end, disposed to suit the projections upon the cage. That end of each roller which is to be disposed towards the larger end of the cage may have a rounded or conical hole 10, and the spigot-like projection upon the cage at this end is preferably pointed, whilst the other spigot is less in length, and may be rectangular in shape. When it is desired to assemble the rollers in the cage the smaller spigot is bent so as to enable the roller to be placed on the pointed spigot, and when this has been done the smaller spigot is bent back to engage the recess in the end of the roller. (*Accepted December* 17, 1919.)